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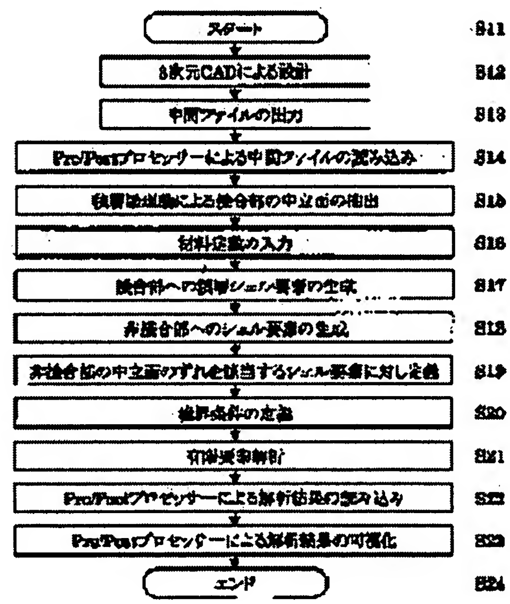
## (54) THREE-DIMENSIONAL CAD/CAE LINK SYSTEM

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a three-dimensional CAD/CAE link system capable of accurately and also quickly performing finite element analysis even to a laminated structure having a connection part laminated by an adhesive layer.
SOLUTION: In steps S12 and S13, three-dimensional CAD data of a three- dimensional shape object is outputted in an intermediate file format, and in a step S14, an intermediate file is read by a Pre/Post processor. In a step S15, a neutral surface on a connected part laminated by an adhesive layer is extracted by using laminated beam theory in a master model composed of three-dimensional shape data automatically generated by the Pre/Post processor. In steps S16 to S18, a laminated shell element is generated at a neutral surface extraction position of the connection part, a shell element is generated at the neutral surface extraction position of a non- connection part, and in a step S19, the deviation of the neutral surfaces of the connection part from the non- connection part is defined to a corresponding shell element and a finite element model is generated. In steps S20 top S23, a finite element analysis is performed by using the finite element model.

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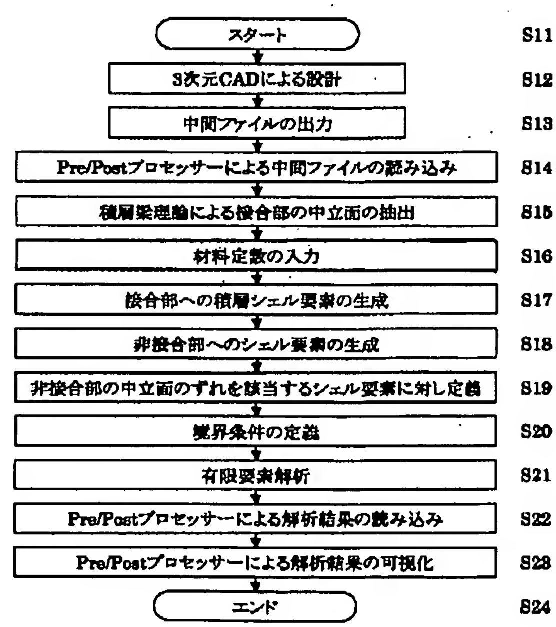
(54)【発明の名称】　３次元ＣＡＤ／ＣＡＥ連成システム

(57)【要約】
【課題】　接着層により積層された接合部を有する積層構造体に対しても正確かつ迅速な有限要素解析が可能な３次元ＣＡＤ／ＣＡＥ連成システムを提供する。
【解決手段】　ステップＳ１２、Ｓ１３において、３次元形状物の３次元ＣＡＤデータを中間ファイル形式で出力し、ステップＳ１４で上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む。ステップＳ１５では上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成された３次元形状データよりなるマスターモデルにおいて、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する。ステップＳ１６、Ｓ１７、Ｓ１８において、上記接合部の中立面抽出位置に積層シェル要素を生成させるとともに、非接合部の中立面抽出位置にシェル要素を生成させ、ステップＳ１９では上記接合部と上記非接合部の中立面のずれを該当するシェル要素に対して定義し、有限要素モデルを生成する。ステップＳ２０、Ｓ２１、Ｓ２２、Ｓ２３では上記有限要素モデルを用いて有限要素解析を行う。



【特許請求の範囲】

【請求項１】　３次元形状物の３次元ＣＡＤデータを、中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成された３次元形状データよりなるマスターモデルにおいて、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたことを特徴とする３次元ＣＡＤ／ＣＡＥ連成システム。

【請求項２】　３次元形状物の３次元ＣＡＤデータより、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記中立面抽出位置を含む３次元ＣＡＤデータを中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成されたマスターモデルにおいて、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたことを特徴とする３次元ＣＡＤ／ＣＡＥ連成システム。

【請求項３】　接合部の中立面抽出位置に積層シェル要素を生成させるとともに、非接合部の中立面抽出位置にシェル要素を生成させる手段、および上記接合部と上記非接合部の中立面のずれを該当するシェル要素に対して定義し、有限要素モデルを生成する手段を備えたことを特徴とする請求項１または２記載の３次元ＣＡＤ／ＣＡＥ連成システム。

【請求項４】　生成した有限要素モデルを用いて有限要素解析を行う手段を備えたことを特徴とする請求項１ないし３のいずれかに記載の３次元ＣＡＤ／ＣＡＥ連成システム。

【請求項５】　３次元形状物は、繊維強化プラスチックよりなる積層構造を有する構造体であることを特徴とする請求項１ないし４のいずれかに記載の３次元ＣＡＤ／ＣＡＥ連成システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、３次元ＣＡＤ（Ｃｏｍｐｕｔｅｒ　Ａｉｄｅｄ　Ｄｅｓｉｇｎ）／ＣＡＥ（Ｃｏｍｐｕｔｅｒ　Ａｉｄｅｄ　Ｅｎｇｉｎｅｅｒｉｎｇ）連成システムに関するものであり、例えばＡｕｔｏ　ＣＡＤ（Ａｕｔｏ　Ｄｅｓｋ社）などの３次元ＣＡＤを用いて設計された３次元形状データをＩＧＥＳ（Ｉｎｉｔｉａｌ　Ｇｒａｐｈｉｃｓ　Ｅｘｃｈａｎｇｅ　Ｓｐｅｃｉｆｉｃａｔｉｏｎ）やＤＸＦ（Ｄｒａｗｉｎｇ　Ｉｎｔｅｒｃｈａｎｇｅ　Ｆｉｌｅ）、ＳＴＥＰ（Ｓｔａｎｄａｒｄ　ｆｏｒ　Ｔｈｅ　Ｅｘｃｈａｎｇｅ　Ｐｒｏｄｕｃｔ　Ｍｏｄｅｌ　Ｄａｔａ）などの中間ファイル形式で出力し、そのファイルをＰｒｅ／Ｐｏｓｔプロセッサーで読み込むことにより、ＣＡＥ解析において用いられるＣＡＥ用有限要素法（Ｆｉｎｉｔｅ　Ｅｌｅｍｅｎｔ　Ｍｅｔｈｏｄ　：　ＦＥＭ）モデル作成のための形状データ（点やカーブで定義されたＳｕｒｆａｃｅと呼ばれる領域のデータ）を自動生成させ、モデル化に要する時間を削減することができる３次元ＣＡＤ／ＣＡＥ連成システムにおいて、特に接着層により積層された積層構造体を対象とする３次元ＣＡＤ／ＣＡＥ連成システムを実現するものである。

【０００２】

【従来の技術】一般に３次元形状物のＦＥＭ解析を行なう場合、対象物を有限要素（Ｆｉｎｉｔｅ　Ｅｌｅｍｅｎｔ）と呼ばれる有限の領域に離散化する必要がある。有限要素の作成には、一般にＰｒｅ／Ｐｏｓｔプロセッサー（例えば、ＳＤＲＣ社製Ｉ－ＤｅａｓやＥＳＰ社製ＦＥＭＡＰなど）と呼ばれるソフトウェアが用いられる。図１７にＰｒｅ／Ｐｏｓｔプロセッサーにおけるモデル化の流れを示す。図１７において、１はカーブ、２は点、３は領域平面、４は（有限）要素、５は節点（ノード）であり、Ｐｒｅ／Ｐｏｓｔプロセッサーを用いて要素４を生成させるには、モデル化対象における要素生成領域を定義する必要がある。要素生成領域は、２次元平面の場合、点２、カーブ１で定義された領域平面３（Ｓｕｒｆａｃｅと呼ぶことにする）、３次元立体の場合、Ｓｕｒｆａｃｅ３で定義された立体（Ｖｏｌｕｍｅと呼ぶことにする）が必要となる。図１７においては、まず、ステップＳ１で各点２の座標を入力し、ステップＳ２～Ｓ４で対象物が２次元平面の場合、点２、カーブ１で定義された領域平面３、３次元立体の場合、Ｓｕｒｆａｃｅ３で定義された立体を生成する。次に、ステップＳ５、Ｓ６では要素４の材料特性および形状特性を定義し、さらにステップＳ７では要素分割数を定義して、ステップＳ８で要素を生成する。このようにして得られた要素に対して、境界条件を設定して解析を実行する（ステップＳ９、Ｓ１０）。

【０００３】これらのステップを実行するにあたり、これまでは設計図面から座標を作業者が読み取り、手入力していたが、近年の３次元ＣＡＤの普及により、自動生成させることが可能となっている。例えばＡｕｔｏ　ＣＡＤ（Ａｕｔｏ　Ｄｅｓｋ社）などの３次元ＣＡＤを用いて設計されたものの３次元形状データをＩＧＥＳやＤＸＦなどの中間ファイルに出力し、そのファイルをＰｒｅ／Ｐｏｓｔプロセッサーで読み込むことができる。読み込まれたデータは、図１８にその一例を示すように、設計された製品をポイント、カーブで定義した３次元形状データ（マスターモデル）が含まれている。図１８に示す３次元形状データ（マスターモデル）をもとに、有限要素を自動生成したものが図１９である。最近のＰｒｅ／Ｐｏｓｔプロセッサーにおいては、図１９に示すよ

うに、3次元CADデータから読み取ったＶｏｌｕｍｅ内に四面体要素６を生成させる機能を有しており、従来手作業で行なっていた図１７中のステップＳ１～Ｓ４、およびステップＳ８を自動で行なえる。

【０００４】一方、薄板構造物などのモデル化対象物において、平面応力状態（Ｐｌａｎｅｓｔｒｅｓｓ）が仮定できる場合、対象物を２次元平面応力要素（シェル要素）で離散化（モデル化）できる。シェル要素は通常、板厚の中間に位置する面（中立面）を作成してメッシュを作成する。薄板構造物であれば、十分な精度が得られる。板厚方向のモデル化が不要なためメッシュが簡略化でき、解析時間を短縮できる。

【０００５】3次元CADからＰｒｅ／Ｐｏｓｔプロセッサーへ渡された３次元形状データ（マスターモデル）より、中立面を自動的に抽出する方法は、例えば日経メカニカル（１９９６．３．４ Ｎｏ．４７５ ｐ．６３）に公開されている。図２０、２１に示すように、薄板構造のマスターモデル９において、断面７に対して円を描写し、その中心を線でつなぐことで中立軸８を抽出する（円描写法と称する）。このようにして３次元薄板構造物に対し、円描写法により抽出した中立面１０が図２１である。

【０００６】

【発明が解決しようとする課題】従来の３次元ＣＡＤ／ＣＡＥ連成システムは以上のようにしてＣＡＥとの連成を行っていた。次に、薄板構造物において接着層により積層された接着接合部を含む構造体を対象とする場合の3次元ＣＡＤ／ＣＡＥ連成システムについて説明する。上記構造体を３次元ＣＡＤで設計する場合、図２２（ｂ）に示すように、極薄である接着層１２は図面化しない場合が多く、Ｐｒｅ／Ｐｏｓｔプロセッサーで読み込んだマスターモデルに接着層がない形で読み込まれる。なお、図２２（ａ）は設計対象である薄板接着継手であり、図２２（ｂ）は3次元ＣＡＤデータ、図２２（ｃ）はＰｒｅ／Ｐｏｓｔプロセッサーで読み込んだマスターモデルである。また、図２２において、１１は被着体Ａ、１２は接着層、１３は被着体Ｂ、１４は3次元ＣＡＤデータから読み取ったカーブ、１５　3次元ＣＡＤデータから読み取ったポイントである。

【０００７】図２3は、Ｐｒｅ／Ｐｏｓｔプロセッサーで読み込んだ上記マスターモデルに対して、上下被着体Ａ、Ｂの中立面を円描写法で抽出し、シェル要素１６、１７を生成したものであるが、図２３に示すように、従来の積層構造体を対象とした３次元ＣＡＤ／ＣＡＥ連成システムでは、接着されていることをモデル化できず、接着継手であることを考慮した解析が不可能である。

【０００８】仮に、図24（ａ）（ｂ）（ｃ）に示すように、接着層１２を３次元ＣＡＤで図面化し、Ｐｒｅ／Ｐｏｓｔプロセッサーへ読み込めば、接着層１８がマスターモデルに含まれた状態となる。このようなマスターモデルに対し、図２５（ａ）に示すように、３次元立体要素１９を生成させることで、接着層を考慮したモデル化および有限要素解析が可能になる。なお、図２５（ｂ）は立体要素を用いたシングルラップ接着継手モデルの端部に引張荷重２０を負荷した場合の変形状態解析結果を示した図である。

【０００９】しかしながら、上記のような方法によりモデル化し、有限要素解析を行った場合、極薄である接着層の厚さが要素分割度合いの基準となるため、解析精度上大きな縦横比の要素を許容できない立体要素によるモデル化では、要素数の膨大化を招き、実製品などの複雑３次元形状物に適用する場合、計算時間が長くなるばかりでなく、計算機の容量オーバーにより解析不能になるケースが多発する。

【００１０】一方、図２４（ｃ）に示されるマスターモデルに対し、図２６に示すように、上下被着体１１、１３および接着層に円描写法を適用し、シェル要素によりモデル化することで、計算量の削減は可能となるが、被着体１１、１３の中立面上に生成したシェル要素１６、１７、および接着層の中立面上に生成したシェル要素２１間の結合がなされず、接着されていることをモデル化することができないという問題がある。

【００１１】上記問題点を解決できる有限要素モデリング方法として、"積層シェル要素モデル"が提案されている。図２７に示すように、接合部を、被着体１１、接着層１２、被着体１３の積層板ととらえることにより、積層理論（ＬａｍｉｎａｔｅＴｈｅｏｒｙ）が適用でき、積層板としての等価弾性特性（弾性率や線膨張係数など）を求め、要素特性として与えることでシェル要素（積層シェル要素と呼ぶことにする）でモデル化（離散化）することができる。即ち、積層板としてとらえられた接合部に対し、円描写法で抽出された面上に積層シェル要素２５を生成することにより、接合部を積層シェル要素化し、非接合部に対しては被着体１１、１３の中立面にシェル要素２２、２３を生成し、積層シェル要素２５との間に生じたギャップは、節点間の剛体リンク２６で結合する。

【００１２】しかしながら、こような方法によりモデル化し、有限要素解析を行った場合、接合部に対し、円描写法で抽出した中立面の位置は、接合部すべての板厚の１／２の位置（すなわち図心）となるが、被着体１１、１３の材質および板厚が同一でない限り、接合部の真の中立面２４は図心を通らない。そのため、円描写法で抽出した位置に積層シェル要素２５を生成させた場合、真の中立面２４との間にずれが生じ、正確な有限要素解析が不可能であるという問題があった。

【００１３】この発明は、上記のような課題を解消するためになされたものであり、接着層により積層された接合部を有する積層構造体に対しても正確かつ迅速な有限要素解析が可能な３次元ＣＡＤ／ＣＡＥ連成システムを

提供することを目的とする。
【0014】
【課題を解決するための手段】この発明の第１の構成による３次元ＣＡＤ／ＣＡＥ連成システムは、３次元形状物の３次元ＣＡＤデータを、中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成されたマスターモデルにおいて、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたものである。
【0015】また、この発明の第２の構成による３次元ＣＡＤ／ＣＡＥ連成システムは、３次元形状物の３次元ＣＡＤデータより、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記中立面抽出位置を含む３次元ＣＡＤデータを中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、および上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成されたマスターモデルにおいて、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたものである。
【0016】また、この発明の第３の構成による３次元ＣＡＤ／ＣＡＥ連成システムは、第１または第２の構成において、接合部の中立面抽出位置に積層シェル要素を生成させるとともに、非接合部の中立面抽出位置にシェル要素を生成させる手段、および上記接合部と上記非接合部の中立面のずれを該当するシェル要素に対して定義し、有限要素モデルを生成する手段を備えたものである。
【0017】また、この発明の第４の構成による３次元ＣＡＤ／ＣＡＥ連成システムは、第１ないし第３のいずれかの構成において、生成した有限要素モデルを用いて有限要素解析を行う手段を備えたものである。
【0018】また、この発明の第５の構成による３次元ＣＡＤ／ＣＡＥ連成システムは、第１ないし第４のいずれかの構成において、３次元形状物が、繊維強化プラスチックよりなる積層構造を有する構造体であるものである。
【0019】
【発明の実施の形態】実施の形態１．前述したように、積層構造体における構造解析において、均一材の場合は、接合部における中立面は断面の図心を通るが、通常の積層板の場合、対称積層など特殊な積層構成を除き、図心を通らない。そのため、従来のように円描写法で中立面を求めることができない。本発明では積層梁理論により中立面を抽出して、積層シェル要素生成位置を正確に決定するとともに、このような積層シェル要素モデルを用いて、３次元ＣＡＤを用いた設計からＣＡＥによる構造解析シミュレーション（線形および非線形応力解析や熱応力解析など）までを正確かつ迅速に、自動で実施可能とするものである。
【0020】以下に本発明の実施の形態を説明する。図１は積層梁理論による中立面について説明する説明図であり、ｎ層からなる積層板の断面に対し、任意の軸ｙ、ｚをとったものである。図１において、２７ａは１層目の積層、２７ｂは２層目の積層、２７ｃはｎ層目の積層、２８は積層板の中立面であり、例えば文献「ＦＲＰ構造強度計算の実際」（植村益次著、Ｐ．５８、１９８４）に記載されるように、各層の、弾性率、厚さをそれぞれＥｘｉ、Ａｉとすると、積層板の中立面２８の位置は
【0021】
【数１】

$$z_0 = \frac{\sum_{i=1}^{n} E_{x1} A_i z_{0i}}{\sum_{i=1}^{n} E_{x1} A_i} \qquad (1)$$

【0022】として与えられる。従来の円描写法ではなく、上記式（１）を用いて積層板の中立面の位置を決定することにより、真の積層シェル要素２４生成位置を決定することができる。
【0023】図２に、本発明の実施の形態１による３次元ＣＡＤ／ＣＡＥ連成システムのフローチャートを示す。本実施の形態では、図２２に示すようなシングルラップ接着継手への適用例を示す。ステップＳ１２において対象物を３次元ＣＡＤで設計し、ＩＧＥＳ、ＤＸＦなどの中間ファイルを出力（ステップＳ１３）した後、Ｐｒｅ／Ｐｏｓｔプロセッサーへ中間ファイルを読み込む（ステップＳ１４）と、図２２（ｃ）のようにポイントおよびカーブで定義した形状データを受け渡すことができる。このようにして得られたマスターモデルにおける接合部に対し、前述の積層梁理論を適用して中立面の位置を決定する（ステップＳ１５）。例えば、板厚３．２ｍｍの鋼鈑（弾性率２１０００ｋｇｆ／ｍｍ²）と板厚１．６ｍｍのアルミニウム板（弾性率７０００ｋｇｆ／ｍｍ²）を０．２ｍｍ厚の接着剤（弾性率１０３ｋｇｆ／ｍｍ²）で接合した場合、式（１）より、中立面の位置は、１．９７ｍｍとなる。仮に円描写法で抽出すると、２．５ｍｍとなり、誤差が生じる。接合部には、抽出した位置に積層板としての等価剛性を有した積層シェル要素を、非接合部には、従来と同様の方法により中立面を決定し、被着体の材料定数を有したシェル要素を生成させる（それぞれステップＳ１６、Ｓ１７、Ｓ１８）。さらに、被着体Ａ、Ｂの中立面と接合部の中立面とのずれをシェル要素中立面のオフセットとして定義す

る（ステップS19）。これにより図3に示すような有限要素モデルが作成できる。図3において、29はグリップ部、30はモデルに負荷した引張荷重である。このモデルに拘束条件および例えば荷重などの境界条件を定義（ステップS20）し、有限要素解析を行なう（ステップS21）。有限要素解析は、例えばMSC／NASTRANやADINA、COSMOS、ANSYSなどの汎用構造解析プログラムが利用できる。解析結果として、例えば要素応力や節点変位などをPre／Postプロセッサーで読み込み（ステップS22）、例えば応力分布図や変形図の表示により解析結果の可視化を行なう（ステップS23）。

【0024】図4に、シングルラップ接着継手の端部を拘束し、他端に引張荷重を負荷した際の、変形状態解析結果を示す。接合されていることにより上下被着体の中立面のずれが生じ、その結果曲げモーメントによる曲げ変形が生じていることをシェル要素単層で解析できている。接合部においては、要素歪から歪－応力変換を用いて各層面内の応力を求めることができるため、接着層面内のみの応力分布図の作成も可能である（図5）。

【0025】図6、図7は本実施の形態に係わる積層シェル要素モデルによる解析結果と従来の立体要素モデルによる解析結果とを比較した図である。図6に示すように、変形量を従来の立体要素モデル解析結果と比較してもほぼ同様の結果が得られている。一方、図7に示すように、計算時間は、立体要素モデルに対し、約1／200の短縮が可能である。この計算量の削減により、複雑三次元形状を呈する実機形状での接着構造体の有限要素解析が可能となる。

【0026】なお、本実施の形態において、被着体11、13は金属材料を積層したものを対象としたが、例えば一方向カーボン繊維やガラス繊維、アラミド繊維などで強化されたプラスチック積層板の場合でも適用可能である。

【0027】実施の形態2．図8は本発明の実施の形態2による3次元CAD／CAE連成システムのフローチャートである。本実施の形態では、ステップS12において対象物を3次元CADで設計した後、構成部材の接合部に対し、前述の積層梁理論を適用して中立面を抽出する（ステップS15）。即ち、図22（a）に示すようなシングルラップ接着継手の場合、図22（b）に示される3次元CADデータの接合部に対して、積層梁理論を適用して中立面を抽出する。その後、接合部の中立面抽出位置を含む3次元CADデータを、IGES、DXFなどの中間ファイル形式で出力し（ステップS13）、Pre／Postプロセッサーへ中間ファイルを読み込む（ステップS14）と、ポイントおよびカーブで定義した形状データを受け渡すことができる。上記接合部の中立面抽出位置は、正しい位置で定義されたポイントおよびカーブとしてPre／Postプロセッサー上にとりこまれる。このようにして得られたマスターモデルに対し、接合部には、前述の中立面抽出位置に積層板としての等価剛性を有した積層シェル要素を、非接合部には、被着体の材料定数を有したシェル要素を生成させる（それぞれステップS16、S17、S18）。さらに、被着体A、Bの中立面と接合部の中立面とのずれをシェル要素中立面のオフセットとして定義する（ステップS19）。これにより実施の形態1と同様の有限要素モデルが作成できる。このモデルに実施の形態1と同様、拘束条件および例えば荷重などの境界条件を定義（ステップS20）し、有限要素解析を行なう（ステップS21～S23）。

【0028】本実施の形態2による解析結果は、実施の形態1と同様、従来の立体要素モデル解析結果とほぼ同様の結果となり、計算時間も著しく短縮する。

【0029】実施の形態3．本実施の形態では、上記実施の形態1または2のシステムを用いて、ハット型補強を接着した構造パネルの解析事例を示す。図9はハット型補強を接着した構造パネルの3次元CADによる設計においてその形状を示した図であり、ハット型補強と構造パネル間が接着接合されている。図9では対称性を利用して1／2に分割している。図において、31は接着接合部、32は構造パネル、33はハット型補強、34はL字型補強である。図10はハット型補強を接着した構造パネルの解析において接着部を示した図であり、接着部には積層シェル要素を生成させ、その他は、パネル材の機械的特性を有したシェル要素を生成させる。図11は生成した有限要素モデルである。

【0030】本モデルにより、接着接合された構造パネルの剛性や接合部の強度評価など、仮想試作が正確かつ迅速に実施できるとともに低コストで実施できる。

【0031】なお、本実施の形態において、構造パネルが、例えば一方向カーボン繊維やガラス繊維、アラミド繊維などで強化されたプラスチック積層板の場合でも適用可能である。

【0032】実施の形態4．本実施の形態では、上記実施の形態1のシステムを用いて、接着接合を適用して組み立てられた制御盤への適用事例を示す。3次元CADで設計された制御盤の各部品を、IGES形式の中間ファイルを通して、例えばFEMAP（ESP社）などのPre／Postプロセッサーで読み込んだ状態を図12および図13に示す。図14は底板と側板の接合部を示す。これら3次元形状データをマスターモデルとして作成した有限要素モデルを図15（a）に示す。図15（b）は図15（a）において、接合部（積層シェル要素）と非接合部（シェル要素）の領域を色分けで示した図であるり、35は積層シェル要素領域、36は非接合部領域である。図16は本発明によるシステムを用いて制御盤の変形解析を行った解析結果を示した図であり、37は変形前、38は変形後の状態を示す。複雑3次元

形状である接着構造体をシェル要素単層でモデル化できていることがわかる。

【0033】本モデルにより、接着接合された制御盤の剛性や接合部の強度評価など、仮想試作が正確かつ迅速に実施できるとともに低コストで実施できる。

【0034】なお、本実施の形態において、制御盤の各部品が、例えば一方向カーボン繊維やガラス繊維、アラミド繊維などで強化されたプラスチック積層板で構成される場合でも適用可能である。

【0035】

【発明の効果】この発明の第１の構成による３次元ＣＡＤ／ＣＡＥ連成システムによれば、３次元形状物の３次元ＣＡＤデータを、中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成されたマスターモデルにおいて、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたので、３次元ＣＡＤデータから正確な積層シェル要素モデルが作成でき、このモデルを用いて有限要素解析（応力解析、熱伝導解析、熱応力解析、固有値解析、動解析など）を行うことにより、コンピュータ上での仮想試作を正確かつ迅速に行えるとともに、低コストで行うことができる。特に、通常の立体要素モデルでは計算量の膨大化を招く複雑３次元形状を示す実機等の接着構造体や積層板に対しても、正確かつ迅速な有限要素解析が可能となる。

【0036】この発明の第２の構成による３次元ＣＡＤ／ＣＡＥ連成システムによれば、３次元形状物の３次元ＣＡＤデータより、接着層により積層された接合部における中立面を積層梁理論を用いて抽出する手段、上記中立面抽出位置を含む３次元ＣＡＤデータを中間ファイル形式で出力する手段、上記中間ファイルをＰｒｅ／Ｐｏｓｔプロセッサで読み込む手段、上記Ｐｒｅ／Ｐｏｓｔプロセッサで自動生成されたマスターモデルにおいて、上記接合部の中立面抽出位置に積層シェル要素を生成させる手段、および上記積層シェル要素を用いて有限要素モデルを生成する手段を備えたので、第１の構成による３次元ＣＡＤ／ＣＡＥ連成システムと同様の効果がある。

【0037】この発明の第３の構成による３次元ＣＡＤ／ＣＡＥ連成システムによれば、第１または第２の構成において、接合部の中立面抽出位置に積層シェル要素を生成させるとともに、非接合部の中立面抽出位置にシェル要素を生成させる手段、および上記接合部と上記非接合部の中立面のずれを該当するシェル要素に対して定義し、有限要素モデルを生成する手段を備えたので、接合部と非接合部とで構成される複雑な３次元形状物に対しても、正確かつ迅速な有限要素解析が可能となる。

【0038】この発明の第４の構成による３次元ＣＡＤ／ＣＡＥ連成システムによれば、第１ないし第３のいずれかの構成において、生成した有限要素モデルを用いて有限要素解析を行う手段を備えたので、正確かつ迅速な有限要素解析が可能となる。

【0039】この発明の第５の構成による３次元ＣＡＤ／ＣＡＥ連成システムによれば、３次元形状物が、繊維強化プラスチックよりなる積層構造を有する構造体であるので、上記構造体において正確かつ迅速な有限要素解析が可能となる。

【図面の簡単な説明】

【図１】　本発明の実施の形態１に係わる積層梁理論における中立面を説明する説明図である。

【図２】　本発明の実施の形態１による３次元ＣＡＤ／ＣＡＥ連成システムにおけるフローチャートを示す図である。

【図３】　本発明の実施の形態１による３次元ＣＡＤ／ＣＡＥ連成システムにより作成した有限要素モデルを示す図である。

【図４】　本発明の実施の形態１による３次元ＣＡＤ／ＣＡＥ連成システムにおける変形状態の解析結果を示す図である。

【図５】　本発明の実施の形態１による３次元ＣＡＤ／ＣＡＥ連成システムにおける変形状態の解析結果を示す図であり、接着層面内の最大主応力分布を示す図である。

【図６】　本発明の実施の形態１に係わる積層シェル要素モデルによる解析結果と従来の立体要素モデルによる解析結果とを比較した図である。

【図７】　本発明の実施の形態１に係わる積層シェル要素モデルによる解析時間と従来の立体要素モデルによる解析時間とを比較した図である。

【図８】　本発明の実施の形態２による３次元ＣＡＤ／ＣＡＥ連成システムにおけるフローチャートを示す図である。

【図９】　本発明の実施の形態３に係わるハット型補強を接着した構造パネルの３次元ＣＡＤによる設計においてその形状を示す図である。

【図１０】　本発明の実施の形態３に係わるハット型補強を接着した構造パネルの解析において接着部を示す図である。

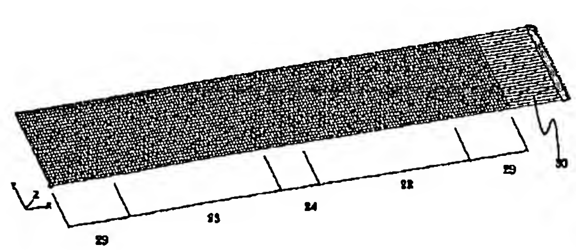
【図１１】　本発明の実施の形態３に係わるハット型補強を接着した構造パネルの有限要素モデルを示す図である。

【図１２】　本発明の実施の形態４に係わる接着接合を適用した制御盤の３次元ＣＡＤ設計データのうち、底板のデータを中間ファイルで出力し、Ｐｒｅ／Ｐｏｓｔプロセッサーで読み込んだ状態を示す図である。

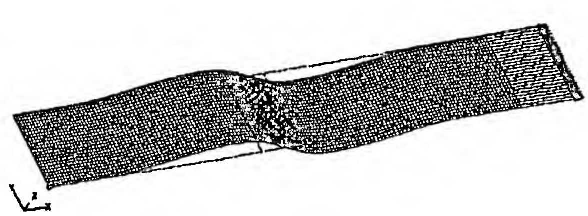
【図１３】　本発明の実施の形態４に係わる接着接合を適用した制御盤の３次元ＣＡＤ設計データのうち、底板

および側板のデータを中間ファイルで出力し、Pre／Postプロセッサーで読み込んだ状態を示す図である。
【図14】 本発明の実施の形態4に係わる接着接合を適用した制御盤の3次元CAD設計データのうち、底板および側板のデータを中間ファイルで出力し、Pre／Postプロセッサーで読み込んだ状態において、接合部を示す図である。
【図15】 本発明の実施の形態4に係わる接着接合を適用した制御盤の有限要素モデルを示す図である。
【図16】 本発明の実施の形態4に係わる制御盤の変形解析の結果を示す図である。
【図17】 Pre／Postプロセッサーにおけるモデル化の流れを示す図である。
【図18】 3次元CADの出力である中間ファイルをPre／Postプロセッサーで読み込んだ状態を示す図である。
【図19】 Pre／Postプロセッサーで読み込まれた3次元形状データに基づいて生成された有限要素を示す図である。
【図20】 円描写法による中立面の抽出を説明する図である。
【図21】 3次元薄板構造物の中立面を円描写法により抽出した事例を示す図である。
【図22】 薄板構造物において接着層により積層された接着接合部を含む構造体において、接着層が図面化されていない3次元CADによる設計とPre／Postプロセッサーへ読み込んだ状態を示す図である。
【図23】 Pre／Postプロセッサーに読み込まれた3次元形状データに対して円描写法により抽出した中立面上にシェル要素を生成させた図である。
【図24】 薄板構造物において接着層により積層された接着接合部を含む構造体において、接着層が図面化されている3次元CADによる設計とPre／Postプロセッサーへ読み込んだ状態を示す図である。
【図25】 Pre／Postプロセッサーに読み込まれた3次元形状データ中に立体要素を生成させて作成した有限要素モデル、および変形状態解析結果を示す図である。
【図26】 薄板構造物において接着層により積層された接着接合部を含む構造体において、接着層が図面化されている3次元CADによる出力ファイルをPre／Postプロセッサーへ読み込み、円描写法により、被着体および接着層の中立面を抽出し、それぞれにシェル要素を生成させた図である。
【図27】 円描写法により得られる中立面の位置と接合部の真の中立面とのずれを示す図である。
【符号の説明】
1 カーブ、2 点、3 Surface、4 (有限)要素、5 節点(ノード)、6 四面体立体要素、7 断面、8 中立軸、9 マスターモデル、10 円描写法により抽出した中立面、11 被着体A、12 接着層、13 被着体B、14 3次元CADデータから読み取ったカーブ、15 3次元CADデータから読み取ったポイント、16 被着体Aの中立面上に生成したシェル要素(平面応力要素)、17 被着体Bの中立面上に生成したシェル要素(平面応力要素)、18 3次元CADから読み込まれた接着層、19 Volume内に生成した立体要素、20 モデルに負荷した引張荷重、21 接着層の中立面上に生成したシェル要素(平面応力要素)、22 積層部の中立面上に生成された被着体A側非接合部のシェル要素(平面応力要素)、23 積層部の中立面上に生成された被着体B側非接合部のシェル要素(平面応力要素)、24 接合部の真の中立面、25 円描写法で抽出された面上に生成された積層シェル要素、26 節点間の剛体リンク、27a 1層目の積層、27b 2層目の積層、27c n層目の積層、28 積層板の中立面、29 グリップ部、30 モデルに負荷した引張荷重、31 接着接合部、32 構造パネル、33 ハット型補強、34 L字型補強、35 積層シェル要素領域、36 非接合部領域、37変形前、38 変形後。

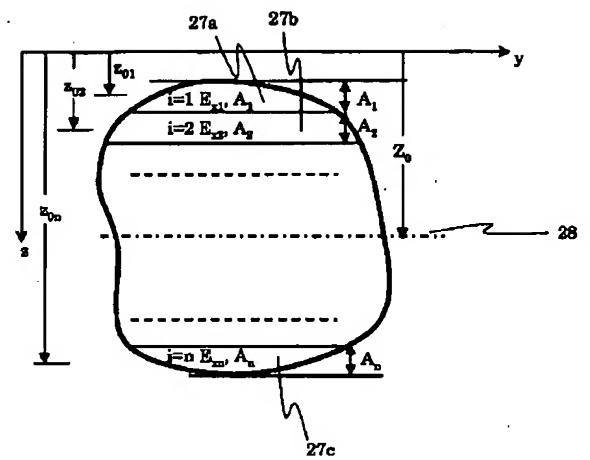
【図3】



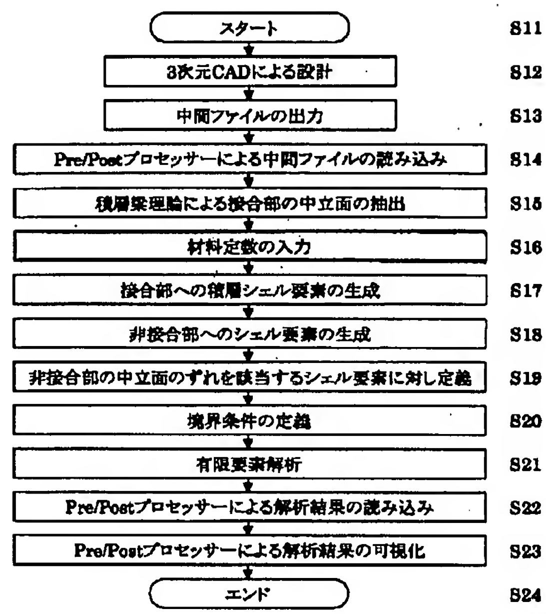

【図4】



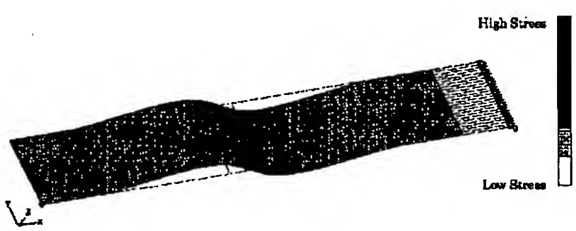
【図1】


27a
27b
y
z
$z_{01}$
$z_{02}$
$z_{0n}$
i=1 $E_{x1}$, $A_1$
i=2 $E_{x2}$, $A_2$
i=n $E_{xn}$, $A_n$
$A_1$
$A_2$
$A_n$
$Z_0$
28
27c

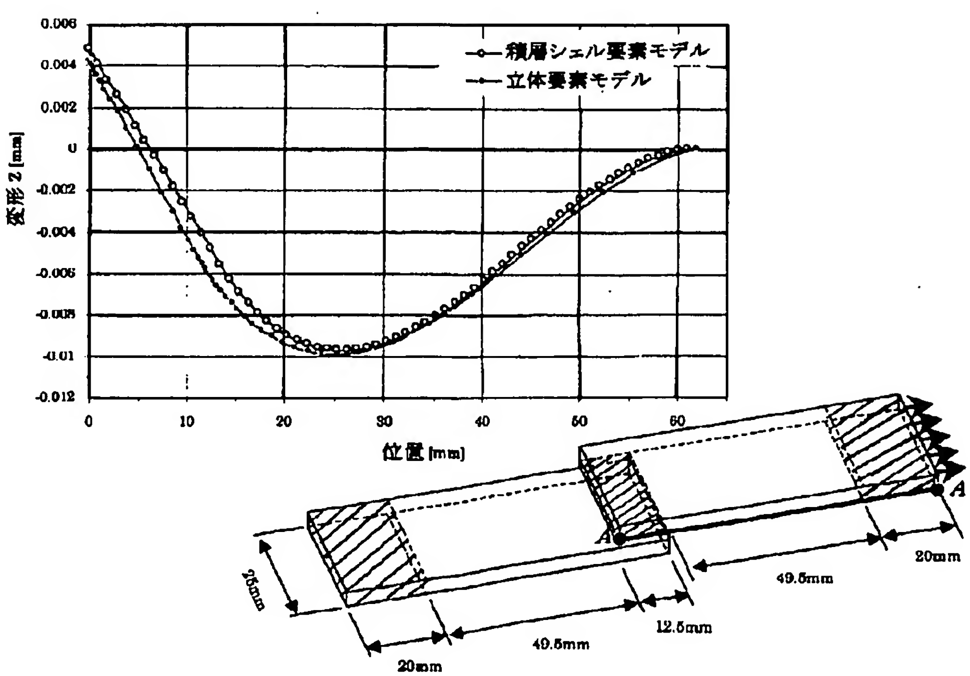
【図2】


スタート S11
3次元CADによる設計 S12
中間ファイルの出力 S13
Pre/Postプロセッサーによる中間ファイルの読み込み S14
積層梁理論による接合部の中立面の抽出 S15
材料定数の入力 S16
接合部への積層シェル要素の生成 S17
非接合部へのシェル要素の生成 S18
非接合部の中立面のずれを該当するシェル要素に対し定義 S19
境界条件の定義 S20
有限要素解析 S21
Pre/Postプロセッサーによる解析結果の読み込み S22
Pre/Postプロセッサーによる解析結果の可視化 S23
エンド S24

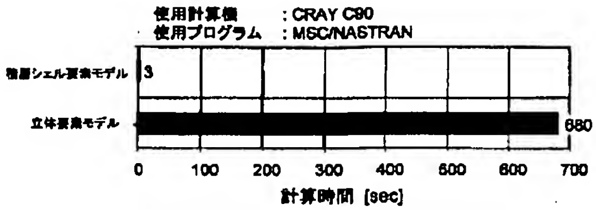
【図5】


High Stress
Low Stress

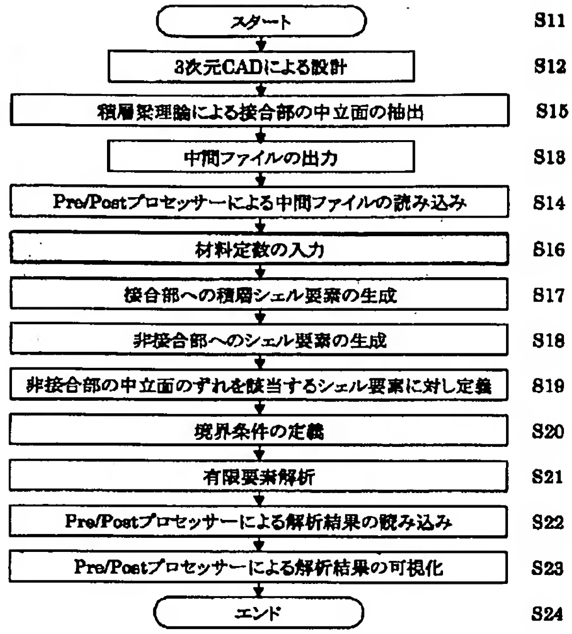
【図6】


積層シェル要素モデル
立体要素モデル
変形 z [mm]
位置 [mm]
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
0
10
20
30
40
50
60
A
A
25mm
20mm
49.5mm
12.5mm
49.5mm
20mm

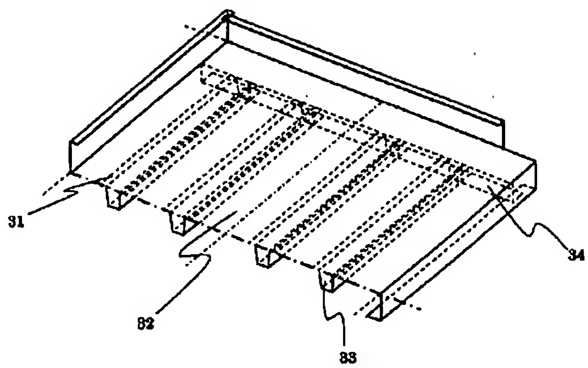
【図7】



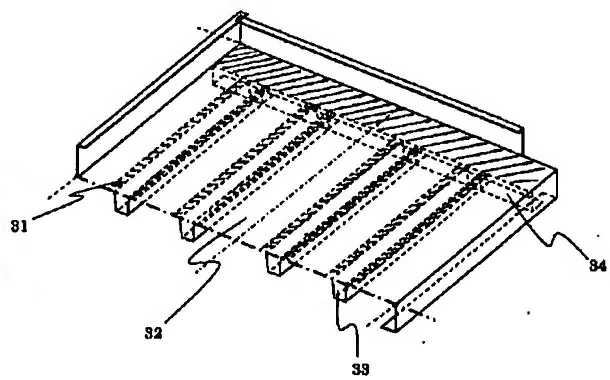

【図8】



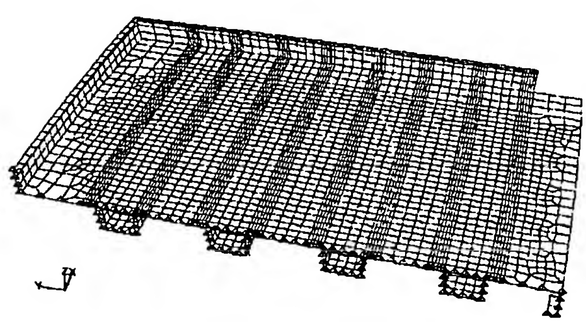

【図9】



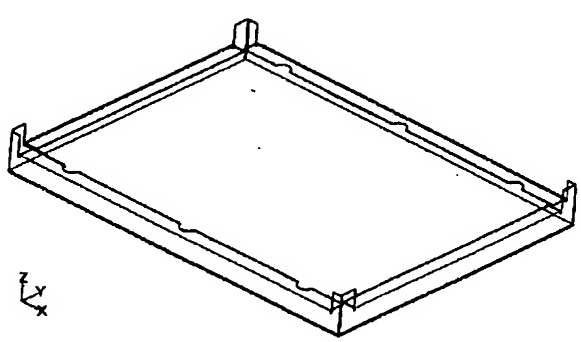

【図10】



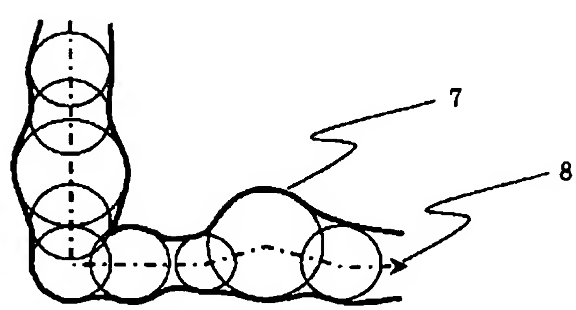

【図11】



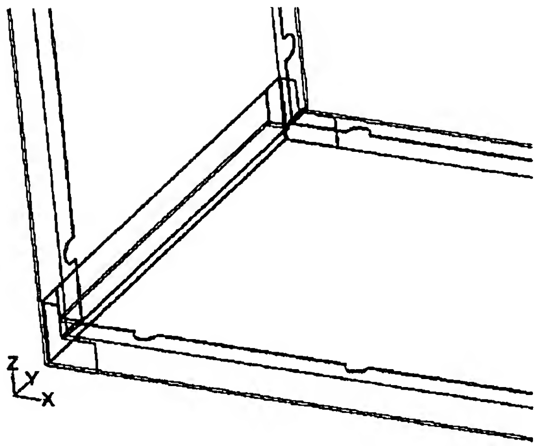
【図12】



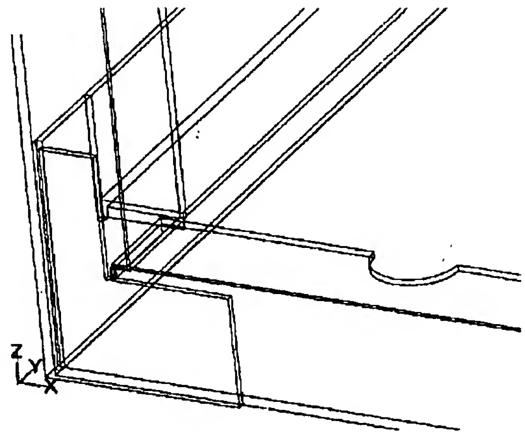
【図20】



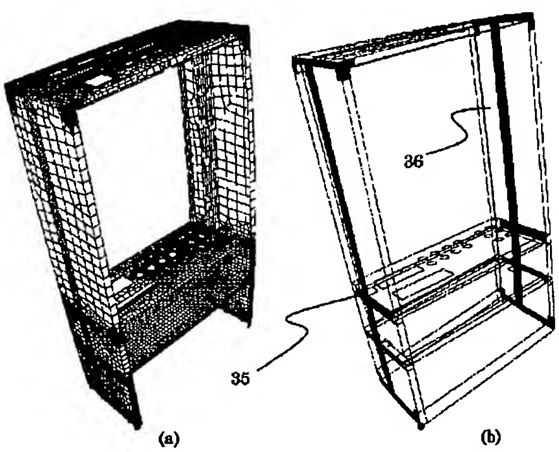
【図13】



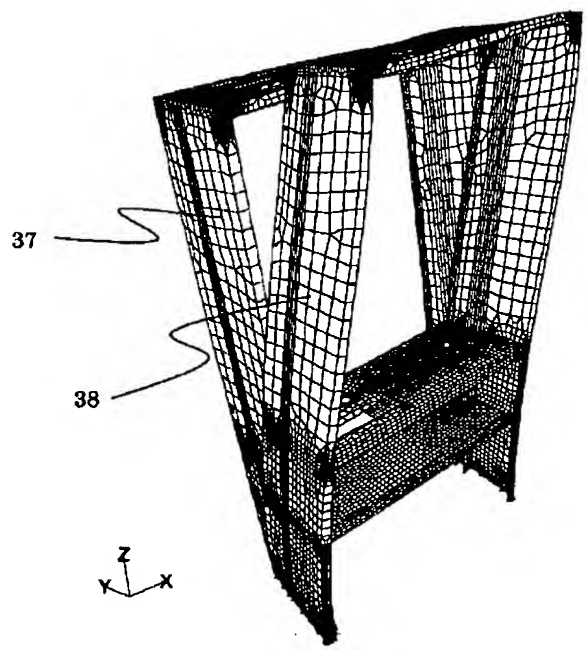
【図14】



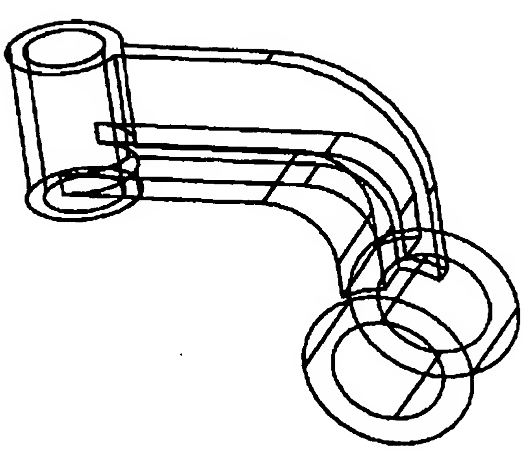
【図15】



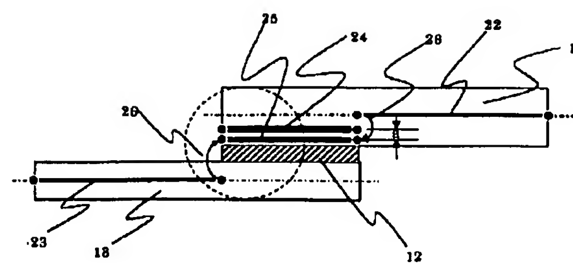

【図16】



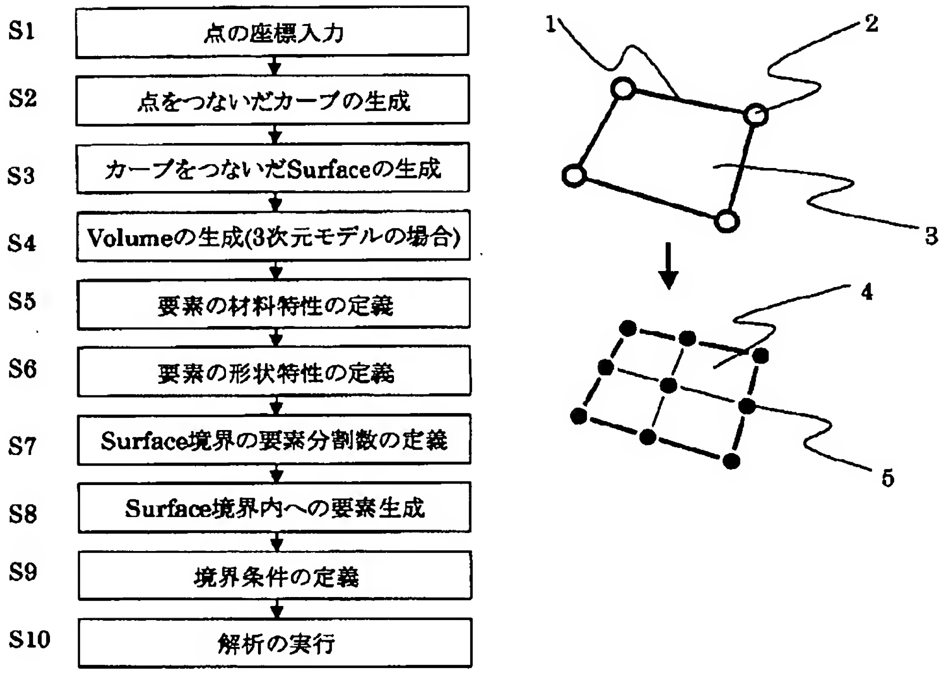

【図18】



【図27】



【図17】

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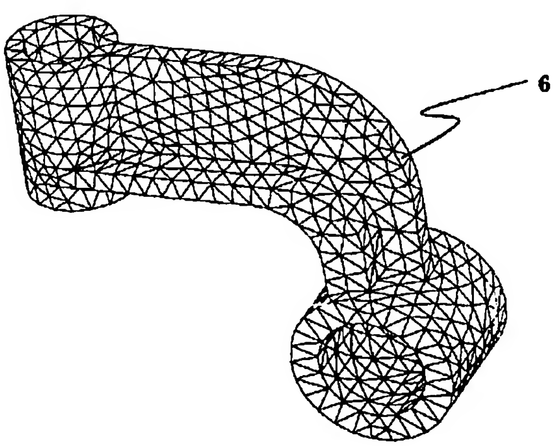
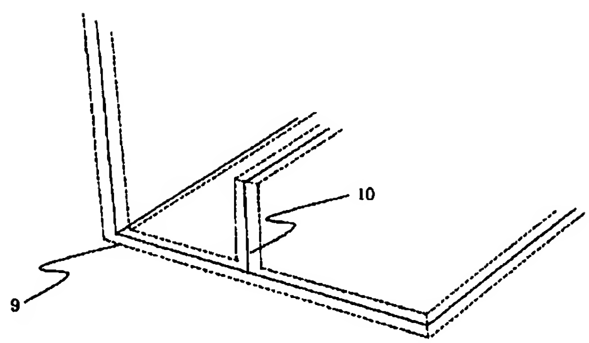
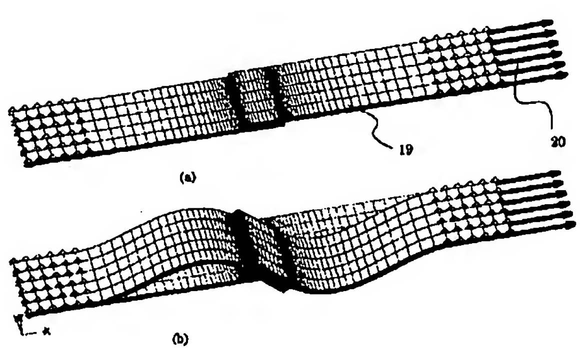


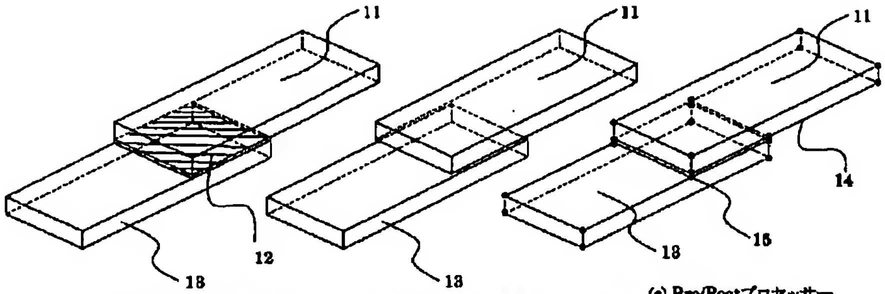

【図21】




【図25】

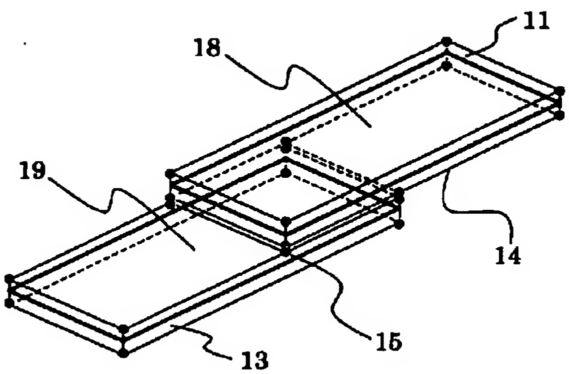


【図22】

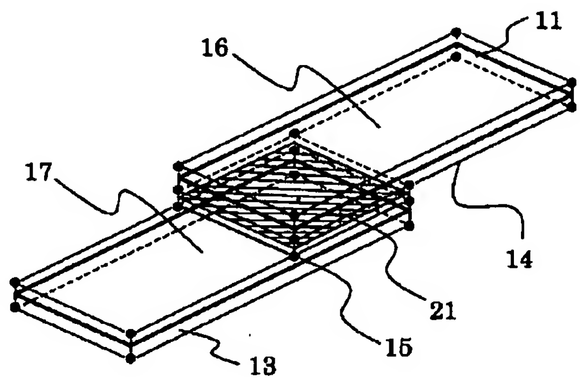



(a) 設計対象薄板接着継手　(b) 3次元CADによる設計例　(c) Pre/Postプロセッサーへ読み込んだ状態(マスターモデル)

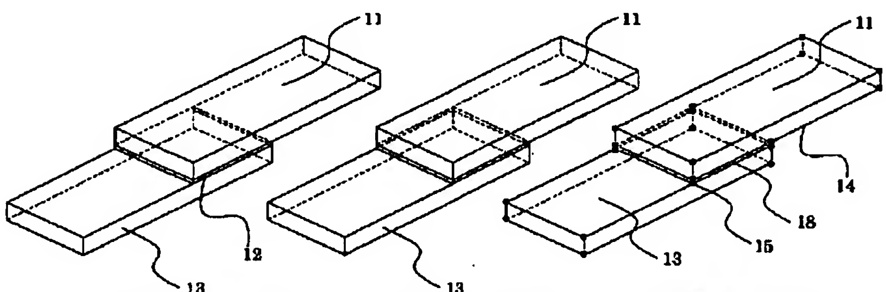
【図23】




【図26】




【図24】




(a) 設計対象薄板接着継手　(b) 3次元CADによる設計例　(c) Pre/Postプロセッサーへ読み込んだ状態(マスターモデル)

* NOTICES *



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CLAIMS

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[Claim(s)]
[Claim 1] A means to output the three-dimensional-CAD data of a three-dimension configuration object in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model which consists of three-dimension configuration data generated automatically by the above-mentioned Pre/Post processor A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line using a laminating beam theory, The three dimensional CAD / CAE manifold-type system characterized by having a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[Claim 2] A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line from the three-dimensional-CAD data of a three-dimension configuration object using a laminating beam theory, A means to output three-dimensional-CAD data including the above-mentioned neutral plane extract location in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor The three dimensional CAD / CAE manifold-type system characterized by having a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[Claim 3] The three dimensional CAD / CAE manifold-type system according to claim 1 or 2 characterized by having a means to define a gap of the neutral plane of a means to make a shell element generate, and the above-mentioned joint and the above-mentioned non-connecting part, to the corresponding shell element as the neutral plane extract location of a non-connecting part, and to generate a finite element model while making the neutral plane extract location of a joint generate a laminating shell element.
[Claim 4] The three dimensional CAD / CAE manifold-type system according to claim 1 to 3 characterized by having a means to perform finite element analysis using the generated finite element model.
[Claim 5] A three-dimension configuration object is the three dimensional CAD / CAE manifold-type system according to claim 1 to 4 characterized by being the structure which has the laminated structure which consists of fiber reinforced plastics.

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[Translation done.]

* NOTICES *

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is a thing about three dimensional CAD (Computer Aided Design) / CAE (Computer Aided Engineering) manifold-type system. For example, they are IGES (Initial Graphics Exchange Specification) and DXF () about the three-dimension configuration data designed using three dimensional CAD, such as Auto CAD (Auto Desk). [ Drawing ] Interchange It outputs in intermediate-file formats, such as File and STEP (Standard for The Exchange Product Model Data). By reading the file by the Pre/Post processor The configuration data (data of the field called Surface defined by the point and the curve) for the finite-element-method (Finite Element Method : FEM) model creation for CAE used in CAE analysis are made to generate automatically. In the three dimensional CAD / CAE manifold-type system which can reduce the time amount which modeling takes, the three dimensional CAD / CAE manifold-type system for the laminating structure in which the laminating was carried out by especially the glue line are realized.
[0002]
[Description of the Prior Art] When performing FEM analysis of a three-dimension configuration object generally, an object needs to be discretized to the field of the finite called a finite element (Finite Element). The software generally called Pre/Post processors (for example, I-Deas made from SDRC, FEMAP by the ESP company, etc.) is used for creation of a finite element. The flow of modeling in a Pre/Post processor is shown in drawing 17 . In drawing 17 , in 1, a curve and 2 need to define the element generation field in the candidate for modeling, in order for a field flat surface and 4 to be joints (node) an element (finite) and 5 and for a point and 3 to make an element 4 generate using a Pre/Post processor. The stereo (referred to as Volume) with which the element generation field was defined by Surface3 in the case of the field flat surface 3 (referred to as Surface) which was defined by the point 2 and the curve 1 in the case of the two-dimensional flat surface, and the three-dimension stereo is needed. In drawing 17 , first, the coordinate of each point 2 is inputted at step S1, and when an object is a two-dimensional flat surface in step S2 - S4, in the case of a point 2, the field flat surface 3 defined by the curve 1, and a three-dimension stereo, the stereo defined by Surface3 is generated. Next, steps S5 and S6 define the material property and shape property of an element 4, step S7 defines the element number of partitions further, and an element is generated at step S8. Thus, to the obtained element, boundary condition is set up and analysis is performed (step S9, S10).
[0003] In performing these steps, the operator was reading and doing the manual entry of the coordinate from the design drawing until now, but it is possible to make it generate automatically by the spread of three dimensional CAD in recent years. For example, Auto Although designed using three dimensional CAD, such as CAD (Auto Desk), three-dimension configuration data are outputted to intermediate files, such as IGES and DXF, and the file can be read by the Pre/Post processor. As the read data show the example to drawing 18 , the three-dimension configuration data (master model) which defined the designed product by the point and the curve are contained. That which generated the finite element automatically based on the three-dimension configuration data (master model) shown in drawing 18 is

drawing 19 . In the latest Pre/Post processor, as shown in drawing 19 , it has the function to make a tetrahedral element 6 generate, in Volume read in three-dimensional-CAD data, and step S1 in drawing 17 which was being performed manually conventionally - S4, and step S8 can be performed automatically.

[0004] On the other hand, in modeling objects, such as the sheet metal structure, when a state of plane stress (Planestress) can be assumed, an object can be discretized with a two-dimensional plane stress element (shell element) (modeling). A shell element usually creates the field (neutral plane) located in the middle of board thickness, and creates a mesh. Sufficient precision will be acquired if it is the sheet metal structure. Since modeling of the direction of board thickness is unnecessary, a mesh can be simplified, and analysis time amount can be shortened.

[0005] The method of extracting a neutral plane from three dimensional CAD automatically from the three-dimension configuration data (master model) passed to the Pre/Post processor is opened to for example, the Nikkei mechanical (1996. 3.4 No.475 p.63). As shown in drawing 20 and 21, in the master model 9 of the thin gauge structure, a circle is described to a cross section 7 and a neutral axis 8 is extracted by connecting the core by the line (the circle describing method is called). Thus, the neutral plane 10 extracted by the circle describing method to the three-dimension sheet metal structure is drawing 2121 .

[0006]

[Problem(s) to be Solved by the Invention] The conventional three dimensional CAD / CAE manifold-type system were performing the manifold type with CAE as mentioned above. Next, the three dimensional CAD / CAE manifold-type system in the case of being aimed at the structure containing the adhesive joint section in which the laminating was carried out by the glue line in the sheet metal structure are explained. When designing the above-mentioned structure by three dimensional CAD, as shown in drawing 22 (b), the ultra-thin glue line 12 is not drawing-ized in many cases, and is read in the form which does not have a glue line in the master model read by the Pre/Post processor. In addition, drawing 22 (a) is a sheet metal bond joint which is a candidate for a design, and is the master model which read drawing 22 (b) by three-dimensional-CAD data, and read drawing 22 (c) by the Pre/Post processor. Moreover, it is the curve from which Adherend A and 12 read 11 and a glue line and 13 read Adherend B and 14 in three-dimensional-CAD data in drawing 22 , and 15. It is the point read in three-dimensional-CAD data.

[0007] Although drawing 23 extracts the neutral plane of the vertical adherends A and B by the circle describing method and generates shell elements 16 and 17 to the above-mentioned master model read by the Pre/Post processor, as shown in drawing 23 , the analysis which could not model having pasted up but took that it was a bond joint into consideration in the three dimensional CAD / CAE manifold-type system for the conventional laminating structure is impossible for it.

[0008] If a glue line 12 is drawing-ized by three dimensional CAD and it reads into a Pre/Post processor as shown in drawing 24 (a), (b), and (c), a glue line 18 will be in the condition of having been contained in the master model. To such a master model, as shown in drawing 25 (a), modeling and finite element analysis in consideration of a glue line become possible by making the three-dimension solid element 19 generate. In addition, drawing 25 (b) is drawing having shown the deformation condition analysis result at the time of carrying out the load of the tension load 20 to the edge of the shingle-lap bond-joint model which used the solid element.

[0009] however, since the thickness of an ultra-thin glue line serve as criteria of an element division degree when a model be make by the above approaches and finite element analysis be perform, when cause huge-ization of the number of elements and apply to complicated three dimension configuration objects, such as a real product, computation time not only become long, but by modeling by the solid element which cannot permit the element of a big aspect ratio on analysis precision, the cases which become analysis impossible by the capacity over of a calculating machine occur frequently.

[0010] On the other hand, although reduction of computational complexity becomes possible to the master model shown in drawing 24 (c) by applying the circle describing method to the vertical adherends 11 and 13 and a glue line, and making a model with a shell element as shown in drawing 26

There is a problem that association between the shell elements 16 and 17 generated on the neutral plane of adherends 11 and 13 and the shell element 21 generated on the neutral plane of a glue line is not made, and it cannot model having pasted up.
[0011] The "laminating shell element model" is proposed as the finite-element-modeling approach which can solve the above-mentioned trouble. As shown in drawing 27 , by catching a joint with the laminate of adherend 11, a glue line 12, and adherend 13, the laminating theory (LaminateTheory) can be applied, the equivalence elasticity (an elastic modulus, coefficient of linear expansion, etc.) as a laminate can be searched for, and a model can be made with a shell element (it will be called a laminating shell element) by giving as an element property (discretization). That is, the gap which formed the joint into the laminating shell element, generated shell elements 22 and 23 to the neutral plane of adherends 11 and 13 to the non-connecting part, and was produced between the laminating shell elements 25 is combined by the rigid-body link 26 during a joint by generating the laminating shell element 25 on the field extracted by the circle describing method to the joint regarded as a laminate.
[0012] However, when a model is made by the approach of coming and finite element analysis is performed, the location of the neutral plane extracted by the circle describing method turns into one half of locations (namely, center of figure) of the board thickness of all joints to a joint, but unless the quality of the material and board thickness of adherends 11 and 13 are the same, the true neutral plane 24 of a joint does not pass along a center of figure. Therefore, when the location extracted by the circle describing method was made to generate the laminating shell element 25, the gap arose between the true neutral planes 24, and there was a problem that exact finite element analysis was impossible.
[0013] This invention is made in order to cancel the above technical problems, and it aims at offering the three dimensional CAD / CAE manifold-type system in which exact and quick finite element analysis is possible also to the laminating structure which has the joint in which the laminating was carried out by the glue line.
[0014]
[Means for Solving the Problem] The three dimensional CAD / CAE manifold-type system by the 1st configuration of this invention In a means to output the three-dimensional-CAD data of a three-dimension configuration object in an intermediate-file format, a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor It has a means to extract the neutral plane in the joint in which the laminating was carried out by the glue line using a laminating beam theory, a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[0015] Moreover, the three dimensional CAD / CAE manifold-type system by the 2nd configuration of this invention A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line from the three-dimensional-CAD data of a three-dimension configuration object using a laminating beam theory, A means to output three-dimensional-CAD data including the above-mentioned neutral plane extract location in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor It has a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[0016] Moreover, in the 1st or 2nd configuration, the three dimensional CAD / CAE manifold-type system by the 3rd configuration of this invention define a gap of the neutral plane of a means to make a shell element generate, and the above-mentioned joint and the above-mentioned non-connecting part, to the corresponding shell element as the neutral plane extract location of a non-connecting part, and is equipped with a means to generate a finite element model while it makes the neutral plane extract location of a joint generate a laminating shell element.
[0017] Moreover, the three dimensional CAD / CAE manifold-type system by the 4th configuration of this invention are equipped with a means to perform finite element analysis using the generated finite element model, in the 1st thru/or the 3rd one of configurations.

[0018] Moreover, the three dimensional CAD / CAE manifold-type system by the 5th configuration of this invention are the structures which have the laminated structure which a three-dimension configuration object becomes from fiber reinforced plastics in the 1st thru/or the 4th one of configurations.
[0019]
[Embodiment of the Invention] As operation did the gestalt 1. above-mentioned of, in the case of homogeneity material, the neutral plane in a joint passes along the center of figure of a cross section in structural analysis in the laminating structure, but in the case of the usual laminate, it does not pass along a center of figure except for a special laminatings configuration, such as an anti-commutator layer. Therefore, a neutral plane cannot be searched for by the circle describing method like before. In this invention, while a laminating beam theory extracts a neutral plane and determining a laminating shell element generation location correctly, operation of from the design using three dimensional CAD to the structural-analysis simulation (linearity, nonlinear stress analysis, thermal stress analysis, etc.) by CAE is enabled [ that it is exact and automatic quickly and ] using such a laminating shell element model.
[0020] The gestalt of operation of this invention is explained below. Drawing 1 R> 1 is an explanatory view explaining the neutral plane by the laminating beam theory, and takes the shafts y and z of arbitration to the cross section of the laminate which consists of n layers. drawing 1 -- setting -- the laminating of the 27a1st layer, and 27b -- the laminating of a two-layer eye, the laminating of the 27cn-th layer, and 28 -- the neutral plane of a laminate -- it is -- for example, reference -- "-- FRP structure count on the strength -- actually -- " (58 the Uemura ******, P. 1984) -- if the elastic modulus of each class and thickness are set to Exi and Ai, respectively so that it may be indicated -- the location of the neutral plane 28 of a laminate -- [0021]
[Equation 1]

$$z_0 = \frac{\sum_{i=1}^{n} E_{x1} A_i z_{0i}}{\sum_{i=1}^{n} E_{x1} A_i} \qquad (1)$$

[0022] It is given by carrying out. A true laminating shell element 24 generation location can be determined by determining the location of the neutral plane of a laminate using the conventional not the circle describing method but above-mentioned formula (1).
[0023] The flow chart of the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention is shown in drawing 2 . The gestalt of this operation shows the example of application to a shingle-lap bond joint as shown in drawing 22 . the Pre/Post processor after designing an object by three dimensional CAD in step S12 and outputting intermediate files, such as IGES and DXF, (step S13) -- an intermediate file -- reading (step S14) -- the configuration data which the point and a curve defined like drawing 22 (c) can be delivered. Thus, with the application of the above-mentioned laminating beam theory, the location of a neutral plane is determined to the joint in the obtained master model (step S15). For example, when the aluminum plate (elastic-modulus 7000kgf/mm2) of 1.6mm of board thickness is joined to the steel plate (elastic-modulus 21000kgf/mm2) of 3.2mm of board thickness with the adhesives (elastic-modulus 103kgf/mm2) of 0.2mm thickness, the location of a neutral plane is set to 1.97mm from a formula (1). If it extracts by the circle describing method, it is set to 2.5mm and an error arises. A neutral plane is determined for a laminating shell element with the equivalent stiffness as a laminate as the extracted location by the same approach as usual at a non-connecting part, and a joint is made to generate a shell element with the ingredient constant of adherend (respectively steps S16, S17, and S18). Furthermore, the gap with the neutral plane of Adherends A and B and the neutral plane of a joint is defined as offset of a shell element neutral plane (step S19). A finite element model as this shows to drawing 3 can be created. In drawing 3 , it is the tension load which made 29 the grip section and made the load of 30 to the model. Boundary condition, such as a constraint and a load, is defined as this model (step S20), and finite element analysis

is performed (step S21). Finite element analysis can use general-purpose structural-analysis programs, such as MSC/NASTRAN, ADINA, COSMOS, and ANSYS. as an analysis result -- for example, element stress and a joint -- about [ strange ] -- etc. -- it reads by the Pre/Post processor (step S22), for example, an analysis result is visualized by the display of a stress distribution Fig. or distored geometry (step S23).

[0024] The edge of a shingle-lap bond joint is restrained to drawing 4 , and the deformation condition analysis result at the time of carrying out the load of the tension load to the other end is shown. It is analyzable by being joined that the gap of the neutral plane of vertical adherend arose and the bending deformation by the bending moment has arisen as a result by the shell element monolayer. In a joint, since it can ask for the stress within a class side using distortion-stress conversion from element distortion, creation of the stress distribution Fig. only within a glue line side is also possible ( drawing 5 ).

[0025] Drawing 6 and drawing 7 are drawings which compared the analysis result by the laminating shell element model concerning the gestalt of this operation with the analysis result by the conventional solid element model. As shown in drawing 6 , even if it measures deformation with the conventional solid element model analysis result, the almost same result is obtained. As shown in drawing 7 on the other hand, compaction of abbreviation 1/200 is possible for computation time to a solid element model. By reduction of this computational complexity, the finite element analysis of the bonded structure object in the system configuration which presents a complicated three-dimensions configuration becomes possible.

[0026] In addition, in the gestalt of this operation, although adherends 11 and 13 were aimed at what carried out the laminating of the metallic material, it is applicable also in the case of the plastics laminate strengthened with one direction carbon fiber, a glass fiber, an aramid fiber, etc., for example.

[0027] Gestalt 2. drawing 8 of operation is the flow chart of the three dimensional CAD / CAE manifold-type system by the gestalt 2 of operation of this invention. With the gestalt of this operation, after designing an object by three dimensional CAD in step S12, with the application of the above-mentioned laminating beam theory, a neutral plane is extracted to the joint of a configuration member (step S15). That is, in the case of a shingle-lap bond joint as shown in drawing 22 (a), with the application of a laminating beam theory, a neutral plane is extracted to the joint of the three-dimensional-CAD data shown in drawing 22 (b). then, three-dimensional-CAD data including the neutral plane extract location of a joint -- intermediate-file formats, such as IGES and DXF, -- outputting (step S13) -- a Pre/Post processor -- an intermediate file -- reading (step S14) -- the configuration data which the point and a curve defined can be delivered. The neutral plane extract location of the above-mentioned joint is crowded for a Pre/Post processor top as the point defined by the right location and a curve. Thus, the above-mentioned neutral plane extract location is made to generate a shell element with the ingredient constant of adherend for a laminating shell element with the equivalent stiffness as a laminate to a non-connecting part to the obtained master model at a joint (respectively steps S16, S17, and S18). Furthermore, the gap with the neutral plane of Adherends A and B and the neutral plane of a joint is defined as offset of a shell element neutral plane (step S19). Thereby, the same finite element model as the gestalt 1 of operation can be created. Boundary condition, such as a constraint and a load, as well as the gestalt 1 of operation is defined as this model (step S20), and finite element analysis is performed (steps S21-S23).

[0028] Like the gestalt 1 of operation, the analysis result by the gestalt 2 of this operation brings the conventional solid element model analysis result and almost same result, and also shortens computation time remarkably.

[0029] The gestalt of gestalt 3. book implementation of operation shows the analysis example of a structure panel where hat mold reinforcement was pasted up, using the system of the gestalten 1 or 2 of the above-mentioned implementation. Drawing 9 is drawing having shown the configuration in the design by the three dimensional CAD of a structure panel which pasted up hat mold reinforcement, and between structure panels is joined to hat mold reinforcement with glue. In drawing 9 , it is dividing into one half using symmetric property. For 31, as for a structure panel and 33, in drawing, the adhesive joint

section and 32 are [ hat mold reinforcement and 34 ] L character mold reinforcement. Drawing 10 is drawing having shown jointing in the analysis of the structure panel on which hat mold reinforcement was pasted up, jointing is made to generate a laminating shell element, and others make a shell element with the mechanical property of panel material generate. Drawing 11 R> 1 is the generated finite element model.

[0030] While a virtual prototype can carry out correctly and quickly evaluation of the rigidity of the structure panel joined with glue, or a joint on the strength etc. with this model, it can carry out by low cost.

[0031] In addition, also in the case of the plastics laminate strengthened with for example, one direction carbon fiber, a glass fiber, an aramid fiber, etc., a structure panel can apply in the gestalt of this operation.

[0032] The gestalt of gestalt 4. book implementation of operation shows the application example to the control panel assembled with the application of the adhesive joint using the system of the gestalt 1 of the above-mentioned implementation. The condition of having let the intermediate file of an IGES format pass, for example, having read each part article of the control panel designed by three dimensional CAD by Pre/Post processors, such as FEMAP (ESP company), is shown in drawing 12 R> 2 and drawing 13 . Drawing 14 shows the joint of a bottom plate and a side plate. The finite element model which created these three-dimensions configuration data as a master model is shown in drawing 15 (a). As for ** which is drawing in which drawing 15 (b) showed the field of a joint (laminating shell element) and a non-connecting part (shell element) by classification by color in drawing 15 (a), and 35, a laminating shell element field and 36 are non-connecting part fields. Drawing 16 is drawing having shown the analysis result which performed deformation analysis of a control panel using the system by this invention, and, as for 38, 37 shows the condition after deformation before deformation. It turns out that the bonded structure object which is a complicated three-dimension configuration can be modeled by the shell element monolayer.

[0033] While a virtual prototype can carry out correctly and quickly evaluation of the rigidity of the control panel joined with glue, or a joint on the strength etc. with this model, it can carry out by low cost.

[0034] In addition, in the gestalt of this operation, even when each part article of a control panel consists of plastics laminates strengthened with for example, one direction carbon fiber, a glass fiber, an aramid fiber, etc., it can apply.

[0035]

[Effect of the Invention] According to the three dimensional CAD / the CAE manifold-type system by the 1st configuration of this invention In a means to output the three-dimensional-CAD data of a three-dimension configuration object in an intermediate-file format, a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line using a laminating beam theory, Since it had a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element By being able to create an exact laminating shell element model from three-dimensional-CAD data, and performing finite element analysis (stress analysis, heat transfer analysis, thermal stress analysis, characteristic value analysis, ******, etc.) using this model While being able to perform the virtual prototype on a computer correctly and quickly, it can carry out by low cost. Especially, in the usual solid element model, exact and quick finite element analysis becomes possible also to bonded structure objects and laminates, such as the system in which the complicated three-dimension configuration which causes huge-ization of computational complexity is shown.

[0036] According to the three dimensional CAD / the CAE manifold-type system by the 2nd configuration of this invention A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line from the three-dimensional-CAD data of a three-dimension configuration object using a laminating beam theory, A means to output three-dimensional-CAD data

including the above-mentioned neutral plane extract location in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor Since it had a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element, there is the same effectiveness as the three dimensional CAD / CAE manifold-type system by the 1st configuration.

[0037] While making the neutral plane extract location of a joint generate a laminating shell element in the 1st or 2nd configuration according to the three dimensional CAD / the CAE manifold-type system by the 3rd configuration of this invention Since it had a means to have defined a gap of the neutral plane of a means to make a shell element generate, and the above-mentioned joint and the above-mentioned non-connecting part, to the corresponding shell element as the neutral plane extract location of a non-connecting part, and to generate a finite element model Exact and quick finite element analysis becomes possible also to the complicated three-dimension configuration object which consists of a joint and a non-connecting part.

[0038] Since it had a means to perform finite element analysis in the 1st thru/or the 3rd one of configurations using the generated finite element model according to the three dimensional CAD / the CAE manifold-type system by the 4th configuration of this invention, exact and quick finite element analysis becomes possible.

[0039] According to the three dimensional CAD / the CAE manifold-type system by the 5th configuration of this invention, since a three-dimension configuration object is the structure which has the laminated structure which consists of fiber reinforced plastics, in the above-mentioned structure, the exact and quick finite element analysis of it becomes possible.

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[Translation done.]

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TECHNICAL FIELD

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[Field of the Invention] This invention is a thing about three dimensional CAD (Computer Aided Design) / CAE (Computer Aided Engineering) manifold-type system. For example, they are IGES (Initial Graphics Exchange Specification) and DXF () about the three-dimension configuration data designed using three dimensional CAD, such as Auto CAD (Auto Desk). [ Drawing ] Interchange It outputs in intermediate-file formats, such as File and STEP (Standard for The Exchange Product Model Data). By reading the file by the Pre/Post processor The configuration data (data of the field called Surface defined by the point and the curve) for the finite-element-method (Finite Element Method : FEM) model creation for CAE used in CAE analysis are made to generate automatically. In the three dimensional CAD / CAE manifold-type system which can reduce the time amount which modeling takes, the three dimensional CAD / CAE manifold-type system for the laminating structure in which the laminating was carried out by especially the glue line are realized.

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[Translation done.]

* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

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PRIOR ART

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[Description of the Prior Art] When performing FEM analysis of a three-dimension configuration object generally, an object needs to be discretized to the field of the finite called a finite element (Finite Element). The software generally called Pre/Post processors (for example, I-Deas made from SDRC, FEMAP by the ESP company, etc.) is used for creation of a finite element. The flow of modeling in a Pre/Post processor is shown in drawing 17 . In drawing 17 , in 1, a curve and 2 need to define the element generation field in the candidate for modeling, in order for a field flat surface and 4 to be joints (node) an element (finite) and 5 and for a point and 3 to make an element 4 generate using a Pre/Post processor. The stereo (referred to as Volume) with which the element generation field was defined by Surface3 in the case of the field flat surface 3 (referred to as Surface) which was defined by the point 2 and the curve 1 in the case of the two-dimensional flat surface, and the three-dimension stereo is needed. In drawing 17 , first, the coordinate of each point 2 is inputted at step S1, and when an object is a two-dimensional flat surface in step S2 - S4, in the case of a point 2, the field flat surface 3 defined by the curve 1, and a three-dimension stereo, the stereo defined by Surface3 is generated. Next, steps S5 and S6 define the material property and shape property of an element 4, step S7 defines the element number of partitions further, and an element is generated at step S8. Thus, to the obtained element, boundary condition is set up and analysis is performed (step S9, S10).
[0003] In performing these steps, the operator was reading and doing the manual entry of the coordinate from the design drawing until now, but it is possible to make it generate automatically by the spread of three dimensional CAD in recent years. For example, Auto Although designed using three dimensional CAD, such as CAD (Auto Desk), three-dimension configuration data are outputted to intermediate files, such as IGES and DXF, and the file can be read by the Pre/Post processor. As the read data show the example to drawing 18 , the three-dimension configuration data (master model) which defined the designed product by the point and the curve are contained. That which generated the finite element automatically based on the three-dimension configuration data (master model) shown in drawing 18 is drawing 19 . In the latest Pre/Post processor, as shown in drawing 19 , it has the function to make a tetrahedral element 6 generate, in Volume read in three-dimensional-CAD data, and step S1 in drawing 17 which was being performed manually conventionally - S4, and step S8 can be performed automatically.
[0004] On the other hand, in modeling objects, such as the sheet metal structure, when a state of plane stress (Planestress) can be assumed, an object can be discretized with a two-dimensional plane stress element (shell element) (modeling). A shell element usually creates the field (neutral plane) located in the middle of board thickness, and creates a mesh. Sufficient precision will be acquired if it is the sheet metal structure. Since modeling of the direction of board thickness is unnecessary, a mesh can be simplified, and analysis time amount can be shortened.
[0005] The method of extracting a neutral plane from three dimensional CAD automatically from the three-dimension configuration data (master model) passed to the Pre/Post processor is opened to for example, the Nikkei mechanical (1996. 3.4 No.475 p.63). As shown in drawing 20 and 21, in the master model 9 of the thin gauge structure, a circle is described to a cross section 7 and a neutral axis 8 is

extracted by connecting the core by the line (the circle describing method is called). Thus, the neutral plane 10 extracted by the circle describing method to the three-dimension sheet metal structure is drawing 2121 .

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[Translation done.]

* NOTICES *



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EFFECT OF THE INVENTION

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[Effect of the Invention] According to the three dimensional CAD / the CAE manifold-type system by the 1st configuration of this invention In a means to output the three-dimensional-CAD data of a three-dimension configuration object in an intermediate-file format, a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line using a laminating beam theory, Since it had a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element By being able to create an exact laminating shell element model from three-dimensional-CAD data, and performing finite element analysis (stress analysis, heat transfer analysis, thermal stress analysis, characteristic value analysis, ******, etc.) using this model While being able to perform the virtual prototype on a computer correctly and quickly, it can carry out by low cost. Especially, in the usual solid element model, exact and quick finite element analysis becomes possible also to bonded structure objects and laminates, such as the system in which the complicated three-dimension configuration which causes huge-ization of computational complexity is shown.
[0036] According to the three dimensional CAD / the CAE manifold-type system by the 2nd configuration of this invention A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line from the three-dimensional-CAD data of a three-dimension configuration object using a laminating beam theory, A means to output three-dimensional-CAD data including the above-mentioned neutral plane extract location in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor Since it had a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element, there is the same effectiveness as the three dimensional CAD / CAE manifold-type system by the 1st configuration.
[0037] While making the neutral plane extract location of a joint generate a laminating shell element in the 1st or 2nd configuration according to the three dimensional CAD / the CAE manifold-type system by the 3rd configuration of this invention Since it had a means to have defined a gap of the neutral plane of a means to make a shell element generate, and the above-mentioned joint and the above-mentioned non-connecting part, to the corresponding shell element as the neutral plane extract location of a non-connecting part, and to generate a finite element model Exact and quick finite element analysis becomes possible also to the complicated three-dimension configuration object which consists of a joint and a non-connecting part.
[0038] Since it had a means to perform finite element analysis in the 1st thru/or the 3rd one of configurations using the generated finite element model according to the three dimensional CAD / the CAE manifold-type system by the 4th configuration of this invention, exact and quick finite element analysis becomes possible.
[0039] According to the three dimensional CAD / the CAE manifold-type system by the 5th

configuration of this invention, since a three-dimension configuration object is the structure which has the laminated structure which consists of fiber reinforced plastics, in the above-mentioned structure, the exact and quick finite element analysis of it becomes possible.

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[Translation done.]

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TECHNICAL PROBLEM

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[Problem(s) to be Solved by the Invention] The conventional three dimensional CAD / CAE manifold-type system were performing the manifold type with CAE as mentioned above. Next, the three dimensional CAD / CAE manifold-type system in the case of being aimed at the structure containing the adhesive joint section in which the laminating was carried out by the glue line in the sheet metal structure are explained. When designing the above-mentioned structure by three dimensional CAD, as shown in drawing 22 (b), the ultra-thin glue line 12 is not drawing-ized in many cases, and is read in the form which does not have a glue line in the master model read by the Pre/Post processor. In addition, drawing 22 (a) is a sheet metal bond joint which is a candidate for a design, and is the master model which read drawing 22 (b) by three-dimensional-CAD data, and read drawing 22 (c) by the Pre/Post processor. Moreover, it is the curve from which Adherend A and 12 read 11 and a glue line and 13 read Adherend B and 14 in three-dimensional-CAD data in drawing 22 , and 15. It is the point read in three-dimensional-CAD data.
[0007] Although drawing 23 extracts the neutral plane of the vertical adherends A and B by the circle describing method and generates shell elements 16 and 17 to the above-mentioned master model read by the Pre/Post processor, as shown in drawing 23 , the analysis which could not model having pasted up but took that it was a bond joint into consideration in the three dimensional CAD / CAE manifold-type system for the conventional laminating structure is impossible for it.
[0008] If a glue line 12 is drawing-ized by three dimensional CAD and it reads into a Pre/Post processor as shown in drawing 24 (a), (b), and (c), a glue line 18 will be in the condition of having been contained in the master model. To such a master model, as shown in drawing 25 (a), modeling and finite element analysis in consideration of a glue line become possible by making the three-dimension solid element 19 generate. In addition, drawing 25 (b) is drawing having shown the deformation condition analysis result at the time of carrying out the load of the tension load 20 to the edge of the shingle-lap bond-joint model which used the solid element.
[0009] however, since the thickness of an ultra-thin glue line serve as criteria of an element division degree when a model be make by the above approaches and finite element analysis be perform, when cause huge-ization of the number of elements and apply to complicated three dimension configuration objects, such as a real product, computation time not only become long, but by modeling by the solid element which cannot permit the element of a big aspect ratio on analysis precision, the cases which become analysis impossible by the capacity over of a calculating machine occur frequently.
[0010] On the other hand, although reduction of computational complexity becomes possible to the master model shown in drawing 24 (c) by applying the circle describing method to the vertical adherends 11 and 13 and a glue line, and making a model with a shell element as shown in drawing 26 There is a problem that association between the shell elements 16 and 17 generated on the neutral plane of adherends 11 and 13 and the shell element 21 generated on the neutral plane of a glue line is not made, and it cannot model having pasted up.
[0011] The "laminating shell element model" is proposed as the finite-element-modeling approach which can solve the above-mentioned trouble. As shown in drawing 27 , by catching a joint with the

laminate of adherend 11, a glue line 12, and adherend 13, the laminating theory (LaminateTheory) can be applied, the equivalence elasticity (an elastic modulus, coefficient of linear expansion, etc.) as a laminate can be searched for, and a model can be made with a shell element (it will be called a laminating shell element) by giving as an element property (discretization). That is, the gap which formed the joint into the laminating shell element, generated shell elements 22 and 23 to the neutral plane of adherends 11 and 13 to the non-connecting part, and was produced between the laminating shell elements 25 is combined by the rigid-body link 26 during a joint by generating the laminating shell element 25 on the field extracted by the circle describing method to the joint regarded as a laminate.
[0012] However, when a model is made by the approach of coming and finite element analysis is performed, the location of the neutral plane extracted by the circle describing method turns into one half of locations (namely, center of figure) of the board thickness of all joints to a joint, but unless the quality of the material and board thickness of adherends 11 and 13 are the same, the true neutral plane 24 of a joint does not pass along a center of figure. Therefore, when the location extracted by the circle describing method was made to generate the laminating shell element 25, the gap arose between the true neutral planes 24, and there was a problem that exact finite element analysis was impossible.
[0013] This invention is made in order to cancel the above technical problems, and it aims at offering the three dimensional CAD / CAE manifold-type system in which exact and quick finite element analysis is possible also to the laminating structure which has the joint in which the laminating was carried out by the glue line.

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[Translation done.]

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## MEANS

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[Means for Solving the Problem] The three dimensional CAD / CAE manifold-type system by the 1st configuration of this invention In a means to output the three-dimensional-CAD data of a three-dimension configuration object in an intermediate-file format, a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor It has a means to extract the neutral plane in the joint in which the laminating was carried out by the glue line using a laminating beam theory, a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[0015] Moreover, the three dimensional CAD / CAE manifold-type system by the 2nd configuration of this invention A means to extract the neutral plane in the joint in which the laminating was carried out by the glue line from the three-dimensional-CAD data of a three-dimension configuration object using a laminating beam theory, A means to output three-dimensional-CAD data including the above-mentioned neutral plane extract location in an intermediate-file format, In a means to read the above-mentioned intermediate file by the Pre/Post processor, and the master model generated automatically by the above-mentioned Pre/Post processor It has a means to make the neutral plane extract location of the above-mentioned joint generate a laminating shell element, and a means to generate a finite element model using the above-mentioned laminating shell element.
[0016] Moreover, in the 1st or 2nd configuration, the three dimensional CAD / CAE manifold-type system by the 3rd configuration of this invention define a gap of the neutral plane of a means to make a shell element generate, and the above-mentioned joint and the above-mentioned non-connecting part, to the corresponding shell element as the neutral plane extract location of a non-connecting part, and is equipped with a means to generate a finite element model while it makes the neutral plane extract location of a joint generate a laminating shell element.
[0017] Moreover, the three dimensional CAD / CAE manifold-type system by the 4th configuration of this invention are equipped with a means to perform finite element analysis using the generated finite element model, in the 1st thru/or the 3rd one of configurations.
[0018] Moreover, the three dimensional CAD / CAE manifold-type system by the 5th configuration of this invention are the structures which have the laminated structure which a three-dimension configuration object becomes from fiber reinforced plastics in the 1st thru/or the 4th one of configurations.
[0019]
[Embodiment of the Invention] As operation did the gestalt 1. above-mentioned of, in the case of homogeneity material, the neutral plane in a joint passes along the center of figure of a cross section in structural analysis in the laminating structure, but in the case of the usual laminate, it does not pass along a center of figure except for a special laminatings configuration, such as an anti-commutator layer. Therefore, a neutral plane cannot be searched for by the circle describing method like before. In this invention, while a laminating beam theory extracts a neutral plane and determining a laminating shell element generation location correctly, operation of from the design using three dimensional CAD to the

structural-analysis simulation (linearity, nonlinear stress analysis, thermal stress analysis, etc.) by CAE is enabled [ that it is exact and automatic quickly and ] using such a laminating shell element model.
[0020] The gestalt of operation of this invention is explained below. Drawing 1 R> 1 is an explanatory view explaining the neutral plane by the laminating beam theory, and takes the shafts y and z of arbitration to the cross section of the laminate which consists of n layers. drawing 1 -- setting -- the laminating of the 27a1st layer, and 27b -- the laminating of a two-layer eye, the laminating of the 27cn-th layer, and 28 -- the neutral plane of a laminate -- it is -- for example, reference -- "-- FRP structure count on the strength -- actually -- " (58 the Uemura ******, P. 1984) -- if the elastic modulus of each class and thickness are set to Exi and Ai, respectively so that it may be indicated -- the location of the neutral plane 28 of a laminate -- [0021]
[Equation 1]

$$z_0 = \frac{\sum_{i=1}^{n} E_{x1} A_i z_{0i}}{\sum_{i=1}^{n} E_{x1} A_i} \qquad (1)$$

[0022] It is given by carrying out. A true laminating shell element 24 generation location can be determined by determining the location of the neutral plane of a laminate using the conventional not the circle describing method but above-mentioned formula (1).
[0023] The flow chart of the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention is shown in drawing 2 . The gestalt of this operation shows the example of application to a shingle-lap bond joint as shown in drawing 22 . the Pre/Post processor after designing an object by three dimensional CAD in step S12 and outputting intermediate files, such as IGES and DXF, (step S13) -- an intermediate file -- reading (step S14) -- the configuration data which the point and a curve defined like drawing 22 (c) can be delivered. Thus, with the application of the above-mentioned laminating beam theory, the location of a neutral plane is determined to the joint in the obtained master model (step S15). For example, when the aluminum plate (elastic-modulus 7000kgf/mm2) of 1.6mm of board thickness is joined to the steel plate (elastic-modulus 21000kgf/mm2) of 3.2mm of board thickness with the adhesives (elastic-modulus 103kgf/mm2) of 0.2mm thickness, the location of a neutral plane is set to 1.97mm from a formula (1). If it extracts by the circle describing method, it is set to 2.5mm and an error arises. A neutral plane is determined for a laminating shell element with the equivalent stiffness as a laminate as the extracted location by the same approach as usual at a non-connecting part, and a joint is made to generate a shell element with the ingredient constant of adherend (respectively steps S16, S17, and S18). Furthermore, the gap with the neutral plane of Adherends A and B and the neutral plane of a joint is defined as offset of a shell element neutral plane (step S19). A finite element model as this shows to drawing 3 can be created. In drawing 3 , it is the tension load which made 29 the grip section and made the load of 30 to the model. Boundary condition, such as a constraint and a load, is defined as this model (step S20), and finite element analysis is performed (step S21). Finite element analysis can use general-purpose structural-analysis programs, such as MSC/NASTRAN, ADINA, COSMOS, and ANSYS. as an analysis result -- for example, element stress and a joint -- about [ strange ] -- etc. -- it reads by the Pre/Post processor (step S22), for example, an analysis result is visualized by the display of a stress distribution Fig. or distored geometry (step S23).
[0024] The edge of a shingle-lap bond joint is restrained to drawing 4 , and the deformation condition analysis result at the time of carrying out the load of the tension load to the other end is shown. It is analyzable by being joined that the gap of the neutral plane of vertical adherend arose and the bending deformation by the bending moment has arisen as a result by the shell element monolayer. In a joint, since it can ask for the stress within a class side using distortion-stress conversion from element distortion, creation of the stress distribution Fig. only within a glue line side is also possible ( drawing 5 ).

[0025] Drawing 6 and drawing 7 are drawings which compared the analysis result by the laminating shell element model concerning the gestalt of this operation with the analysis result by the conventional solid element model. As shown in drawing 6 , even if it measures deformation with the conventional solid element model analysis result, the almost same result is obtained. As shown in drawing 7 on the other hand, compaction of abbreviation 1/200 is possible for computation time to a solid element model. By reduction of this computational complexity, the finite element analysis of the bonded structure object in the system configuration which presents a complicated three-dimensions configuration becomes possible.
[0026] In addition, in the gestalt of this operation, although adherends 11 and 13 were aimed at what carried out the laminating of the metallic material, it is applicable also in the case of the plastics laminate strengthened with one direction carbon fiber, a glass fiber, an aramid fiber, etc., for example.
[0027] Gestalt 2. drawing 8 of operation is the flow chart of the three dimensional CAD / CAE manifold-type system by the gestalt 2 of operation of this invention. With the gestalt of this operation, after designing an object by three dimensional CAD in step S12, with the application of the above-mentioned laminating beam theory, a neutral plane is extracted to the joint of a configuration member (step S15). That is, in the case of a shingle-lap bond joint as shown in drawing 22 (a), with the application of a laminating beam theory, a neutral plane is extracted to the joint of the three-dimensional-CAD data shown in drawing 22 (b). then, three-dimensional-CAD data including the neutral plane extract location of a joint -- intermediate-file formats, such as IGES and DXF, -- outputting (step S13) -- a Pre/Post processor -- an intermediate file -- reading (step S14) -- the configuration data which the point and a curve defined can be delivered. The neutral plane extract location of the above-mentioned joint is crowded for a Pre/Post processor top as the point defined by the right location and a curve. Thus, the above-mentioned neutral plane extract location is made to generate a shell element with the ingredient constant of adherend for a laminating shell element with the equivalent stiffness as a laminate to a non-connecting part to the obtained master model at a joint (respectively steps S16, S17, and S18). Furthermore, the gap with the neutral plane of Adherends A and B and the neutral plane of a joint is defined as offset of a shell element neutral plane (step S19). Thereby, the same finite element model as the gestalt 1 of operation can be created. Boundary condition, such as a constraint and a load, as well as the gestalt 1 of operation is defined as this model (step S20), and finite element analysis is performed (steps S21-S23).
[0028] Like the gestalt 1 of operation, the analysis result by the gestalt 2 of this operation brings the conventional solid element model analysis result and almost same result, and also shortens computation time remarkably.
[0029] The gestalt of gestalt 3. book implementation of operation shows the analysis example of a structure panel where hat mold reinforcement was pasted up, using the system of the gestalten 1 or 2 of the above-mentioned implementation. Drawing 9 is drawing having shown the configuration in the design by the three dimensional CAD of a structure panel which pasted up hat mold reinforcement, and between structure panels is joined to hat mold reinforcement with glue. In drawing 9 , it is dividing into one half using symmetric property. For 31, as for a structure panel and 33, in drawing, the adhesive joint section and 32 are [ hat mold reinforcement and 34 ] L character mold reinforcement. Drawing 10 is drawing having shown jointing in the analysis of the structure panel on which hat mold reinforcement was pasted up, jointing is made to generate a laminating shell element, and others make a shell element with the mechanical property of panel material generate. Drawing 11 R> 1 is the generated finite element model.
[0030] While a virtual prototype can carry out correctly and quickly evaluation of the rigidity of the structure panel joined with glue, or a joint on the strength etc. with this model, it can carry out by low cost.
[0031] In addition, also in the case of the plastics laminate strengthened with for example, one direction carbon fiber, a glass fiber, an aramid fiber, etc., a structure panel can apply in the gestalt of this operation.
[0032] The gestalt of gestalt 4. book implementation of operation shows the application example to the

control panel assembled with the application of the adhesive joint using the system of the gestalt 1 of the above-mentioned implementation. The condition of having let the intermediate file of an IGES format pass, for example, having read each part article of the control panel designed by three dimensional CAD by Pre/Post processors, such as FEMAP (ESP company), is shown in drawing 12 R> 2 and drawing 13 . Drawing 14 shows the joint of a bottom plate and a side plate. The finite element model which created these three-dimensions configuration data as a master model is shown in drawing 15 (a). As for ** which is drawing in which drawing 15 (b) showed the field of a joint (laminating shell element) and a non-connecting part (shell element) by classification by color in drawing 15 (a), and 35, a laminating shell element field and 36 are non-connecting part fields. Drawing 16 is drawing having shown the analysis result which performed deformation analysis of a control panel using the system by this invention, and, as for 38, 37 shows the condition after deformation before deformation. It turns out that the bonded structure object which is a complicated three-dimension configuration can be modeled by the shell element monolayer.

[0033] While a virtual prototype can carry out correctly and quickly evaluation of the rigidity of the control panel joined with glue, or a joint on the strength etc. with this model, it can carry out by low cost.

[0034] In addition, in the gestalt of this operation, even when each part article of a control panel consists of plastics laminates strengthened with for example, one direction carbon fiber, a glass fiber, an aramid fiber, etc., it can apply.

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[Translation done.]

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]
[Drawing 1] It is an explanatory view explaining the neutral plane in the laminating beam theory concerning the gestalt 1 of operation of this invention.
[Drawing 2] It is drawing showing the flow chart in the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention.
[Drawing 3] It is drawing showing the finite element model created by the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention.
[Drawing 4] It is drawing showing the analysis result of the deformation condition in the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention.
[Drawing 5] It is drawing showing the analysis result of the deformation condition in the three dimensional CAD / CAE manifold-type system by the gestalt 1 of operation of this invention, and is drawing showing the maximum-principal-stress distribution within a glue line side.
[Drawing 6] It is drawing which compared the analysis result by the laminating shell element model concerning the gestalt 1 of operation of this invention with the analysis result by the conventional solid element model.
[Drawing 7] It is drawing which compared the analysis time amount by the laminating shell element model concerning the gestalt 1 of operation of this invention with the analysis time amount by the conventional solid element model.
[Drawing 8] It is drawing showing the flow chart in the three dimensional CAD / CAE manifold-type system by the gestalt 2 of operation of this invention.
[Drawing 9] It is drawing showing the configuration in the design by the three dimensional CAD of a structure panel which pasted up the hat mold reinforcement concerning the gestalt 3 of operation of this invention.
[Drawing 10] It is drawing showing jointing in the analysis of the structure panel on which the hat mold reinforcement concerning the gestalt 3 of operation of this invention was pasted up.
[Drawing 11] It is drawing showing the finite element model of the structure panel on which the hat mold reinforcement concerning the gestalt 3 of operation of this invention was pasted up.
[Drawing 12] It is drawing showing the condition of having outputted the data of a bottom plate by the intermediate file, and having read them by the Pre/Post processor among the three-dimensional-CAD design datas of the control panel which applied the adhesive joint concerning the gestalt 4 of operation of this invention.
[Drawing 13] It is drawing showing the condition of having outputted the data of a bottom plate and a side plate by the intermediate file, and having read them by the Pre/Post processor among the three-dimensional-CAD design datas of the control panel which applied the adhesive joint concerning the gestalt 4 of operation of this invention.
[Drawing 14] In the condition of having outputted the data of a bottom plate and a side plate by the intermediate file, and having read them by the Pre/Post processor among the three-dimensional-CAD design datas of the control panel which applied the adhesive joint concerning the gestalt 4 of operation

of this invention, it is drawing showing a joint.
[Drawing 15] It is drawing showing the finite element model of the control panel which applied the adhesive joint concerning the gestalt 4 of operation of this invention.
[Drawing 16] It is drawing showing the result of the deformation analysis of the control panel concerning the gestalt 4 of operation of this invention.
[Drawing 17] It is drawing showing the flow of modeling in a Pre/Post processor.
[Drawing 18] It is drawing showing the condition of having read the intermediate file which is the output of three dimensional CAD by the Pre/Post processor.
[Drawing 19] It is drawing showing the finite element generated based on the three-dimension configuration data read by the Pre/Post processor.
[Drawing 20] It is drawing explaining the extract of the neutral plane by the circle describing method.
[Drawing 21] It is drawing showing the example which extracted the neutral plane of the three-dimension sheet metal structure by the circle describing method.
[Drawing 22] In the structure containing the adhesive joint section in which the laminating was carried out by the glue line in the sheet metal structure, a glue line is drawing showing the condition of having read into the design and Pre/Post processor by the three dimensional CAD which is not drawing-ized.
[Drawing 23] It is drawing which made the shell element generate on the neutral plane extracted by the circle describing method to the three-dimension configuration data read into the Pre/Post processor.
[Drawing 24] In the structure containing the adhesive joint section in which the laminating was carried out by the glue line in the sheet metal structure, a glue line is drawing showing the condition of having read into the design and Pre/Post processor by the three dimensional CAD drawing-ized.
[Drawing 25] They are the finite element model which was made to generate a solid element and was created in the three-dimension configuration data read into the Pre/Post processor, and drawing showing a deformation condition analysis result.
[Drawing 26] In the structure containing the adhesive joint section in which the laminating was carried out by the glue line in the sheet metal structure, it is drawing where read the output file by the three dimensional CAD drawing-ized into a Pre/Post processor, and the glue line extracted the neutral plane of adherend and a glue line, and made each generate a shell element by the circle describing method.
[Drawing 27] It is drawing showing the gap with the location of the neutral plane acquired by the circle describing method, and the true neutral plane of a joint.
[Description of Notations]
1 Curve, 2 Point, 3 Surface, 4 (Finite) Element, 5 A joint (node), 6 A tetrahedron solid element, 7 A cross section, 8 Neutral axis, 9 A master model, 10 The neutral plane, 11 which were extracted by the circle describing method Adherend A 12 A glue line, 13 Adherend B, 14 The curve read in three-dimensional-CAD data, 15 The point, 16 which were read in three-dimensional-CAD data The shell element generated on the neutral plane of Adherend A (plane stress element), 17 The shell element generated on the neutral plane of Adherend B (plane stress element), 18 The glue line, 19 which were read from three dimensional CAD The solid element generated in Volume, The tension load, 21 which carried out the load to 20 models The shell element generated on the neutral plane of a glue line (plane stress element), 22 The shell element of the adherend A side non-connecting part generated on the neutral plane of the laminating section (plane stress element), 23 The shell element of the adherend B side non-connecting part generated on the neutral plane of the laminating section (plane stress element), 24 The true neutral plane of a joint, 25 The laminating shell element generated on the field extracted by the circle describing method, 26 The rigid-body link during a joint, 27a The laminating of the 1st layer, 27b The laminating of a two-layer eye, 27c The laminating of the n-th layer, 28 The neutral plane of a laminate, 29 Grip section, 30 The tension load, 31 which carried out the load to the model The adhesive joint section, 32 A structure panel, 33 Hat mold reinforcement, 34 L character mold reinforcement, 35 A laminating shell element field, 36 Before a non-connecting part field and 37 deformation, 38 After deformation.

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[Translation done.]